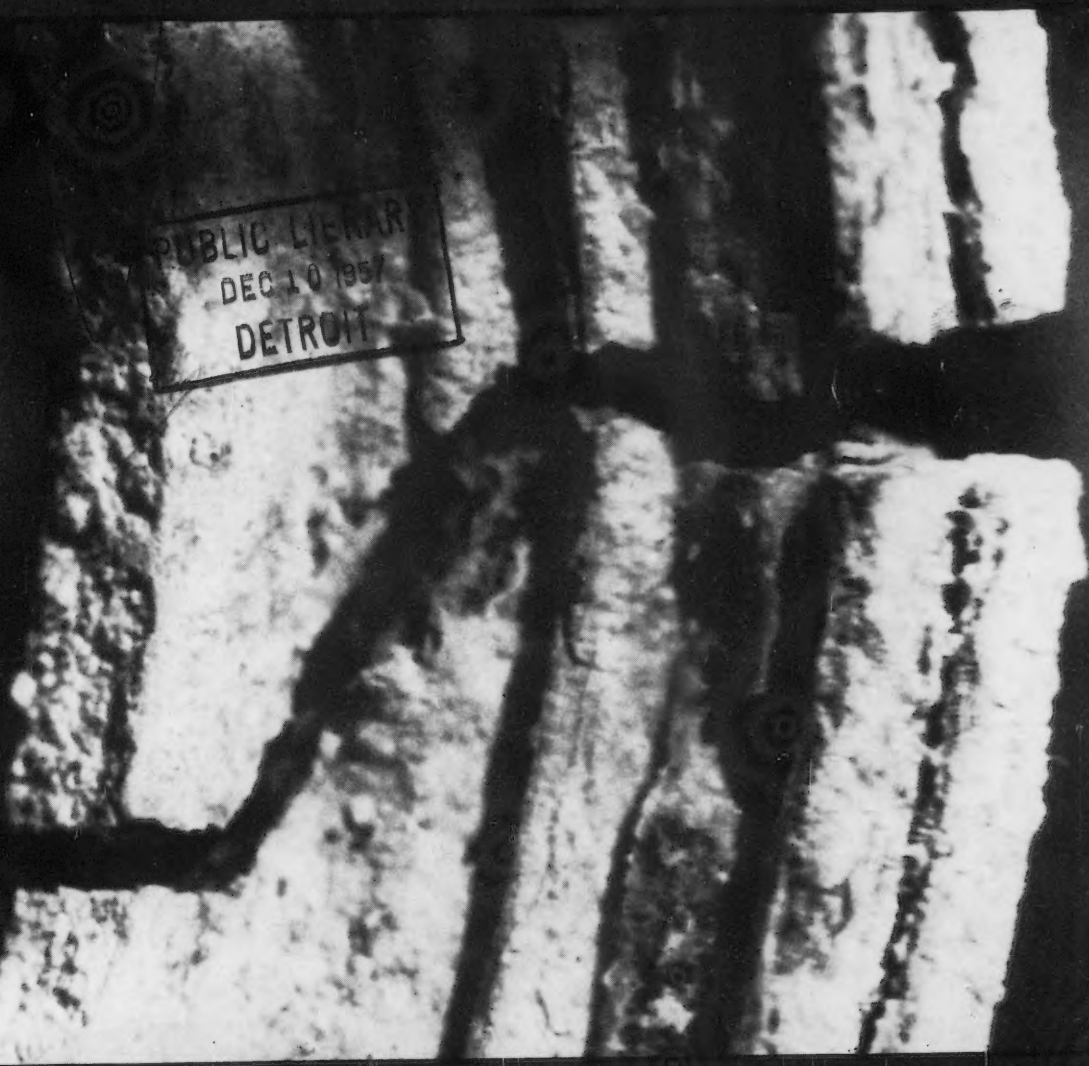


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Corrosion

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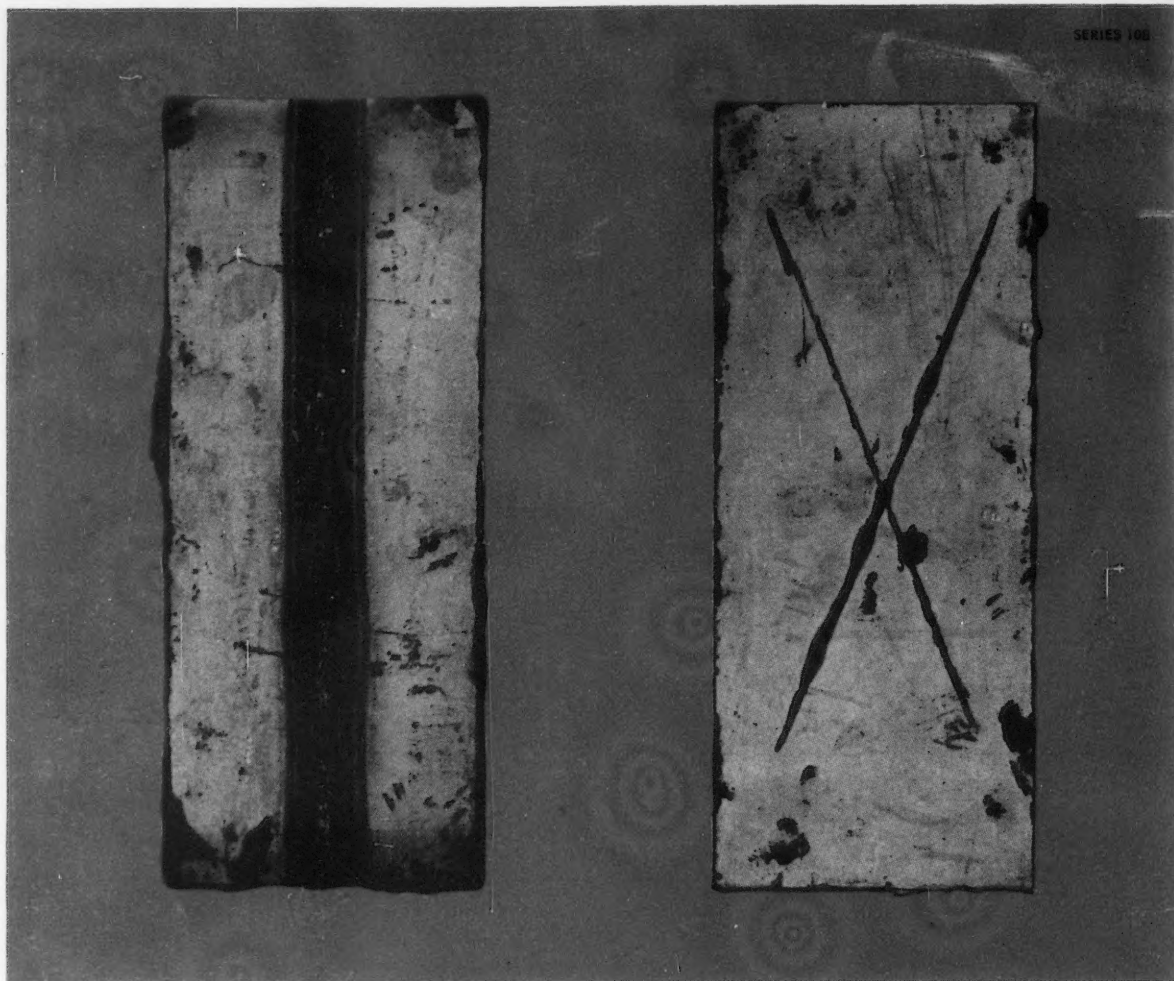
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DECEMBER, 1957

No. 12

IRON



CORROSION'S FOCAL POINTS are easy to detect with a new Amercoat testing method using iron and caustic indicators in a saline gelatin bath. On the welded and scored steel panels shown above after test, unworked surface areas turned red to indicate cathodic properties; but the weld, scores and edges turned

blue (here shown blackened) to reveal themselves as anodic corrosion breeders. Rivets, threads, crevices and abrasions also show anodic under test. Unless such areas are effectively sealed from moisture, oxygen and ions they will erupt as focal points of corrosion cells.

How to protect "trouble spots" against corrosion

Ask a corrosion engineer where metal corrosion is likely to attack first. Chances are that he will name rivets, threads, sharp edges, angles, crevices and welds. These are the areas of stress concentration, work hardness, fissures and abrasions. They tend to be anodic and actually breed corrosion. And although they warrant increased protection, conventional coatings pull away from their sharp profiles and leave them inadequately covered.

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research and control

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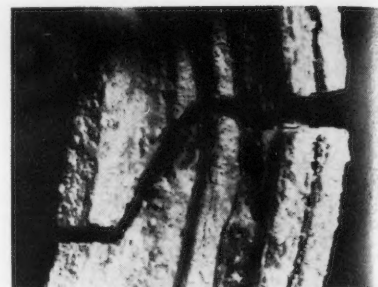
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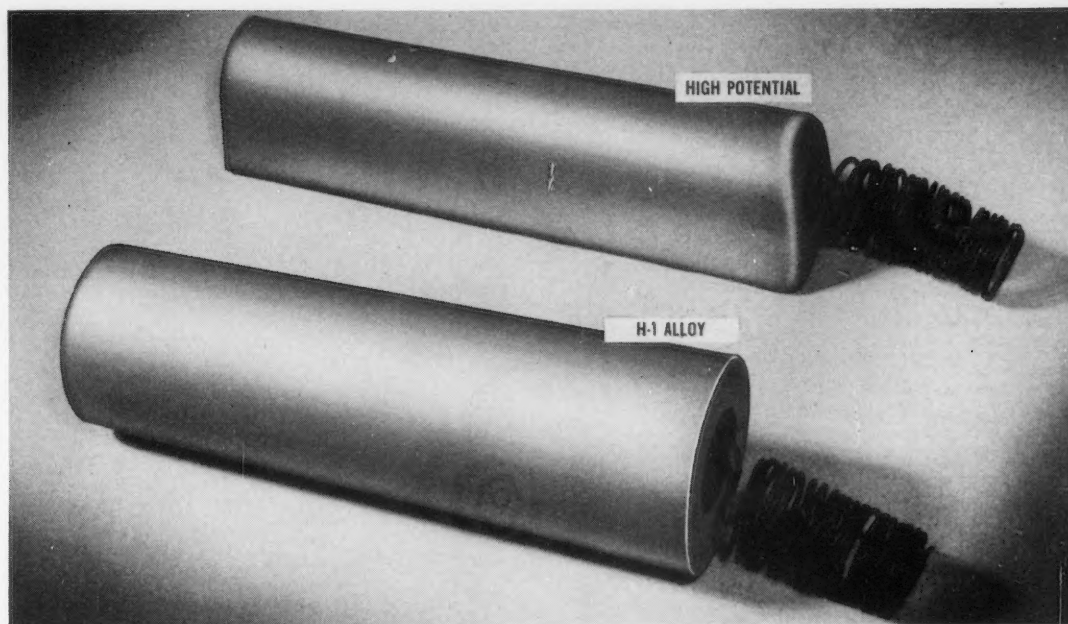
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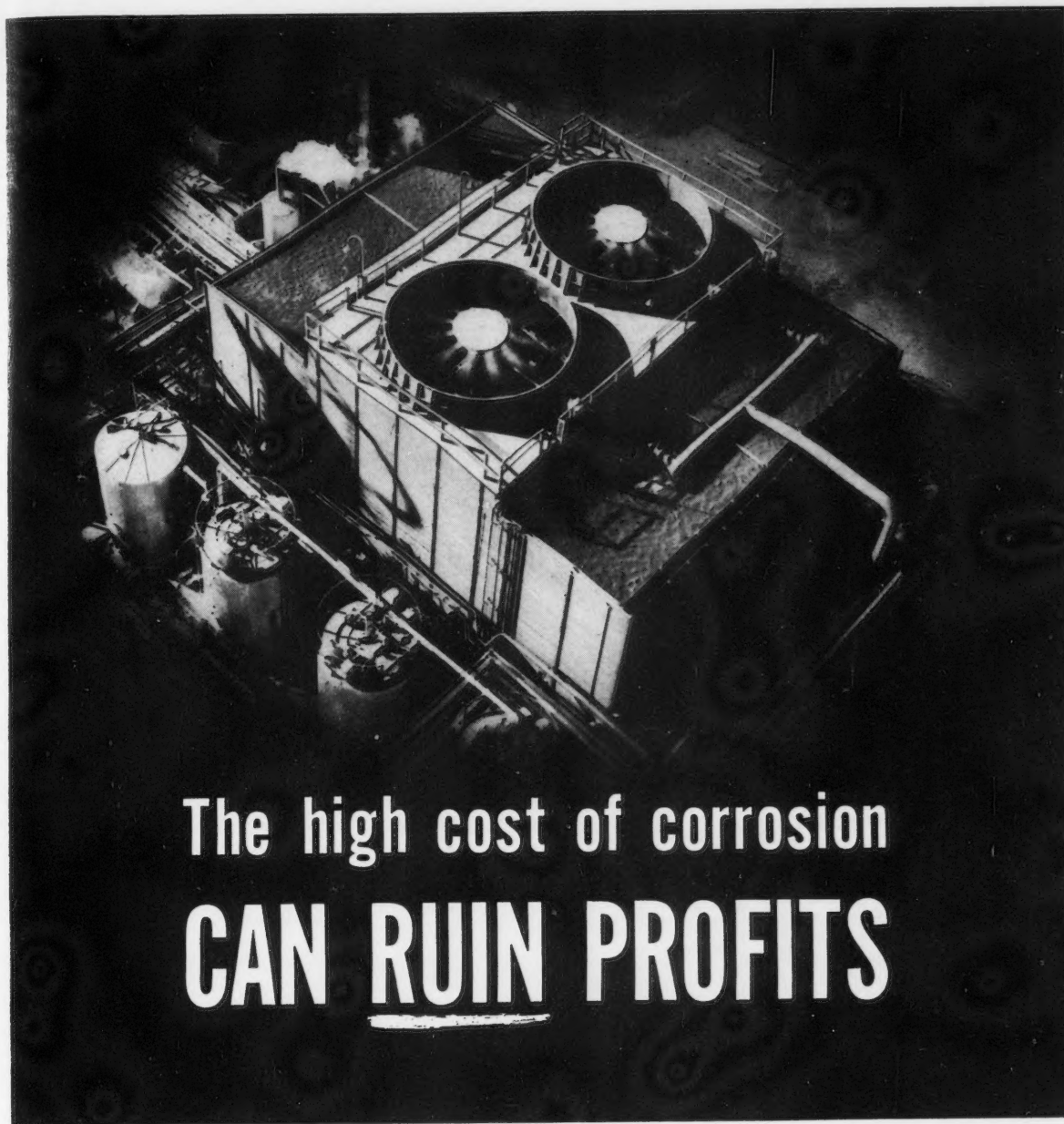
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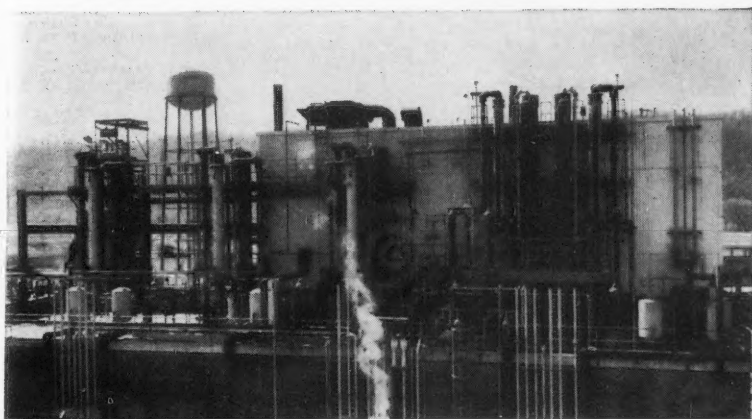
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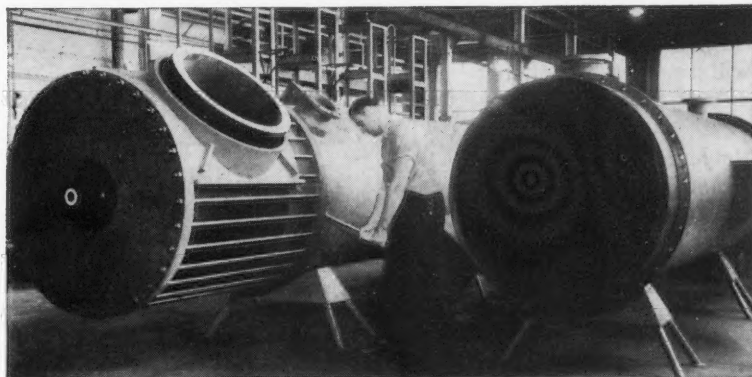
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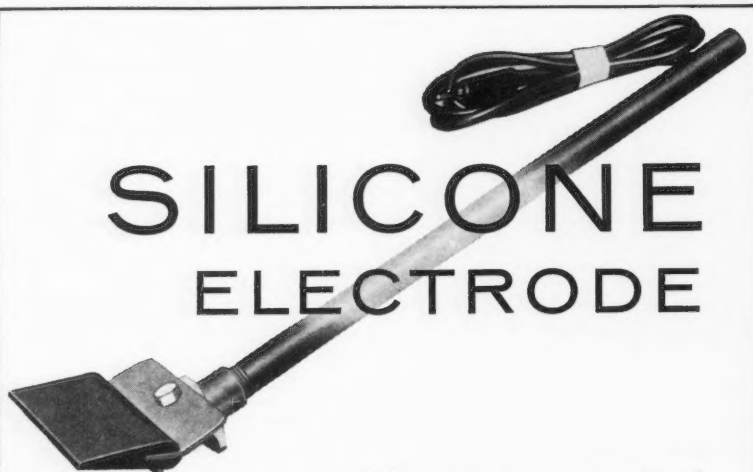
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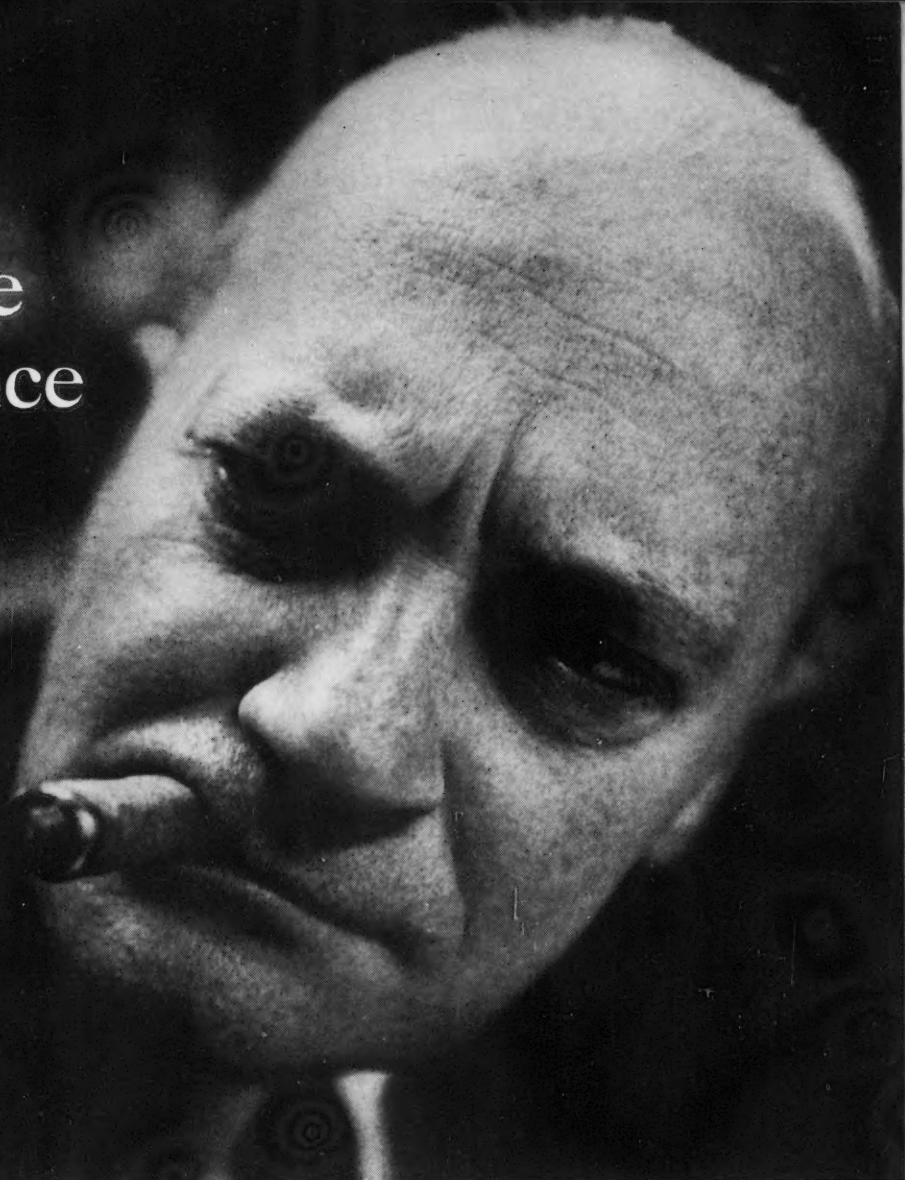
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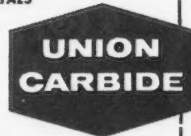
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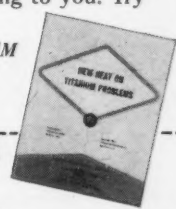
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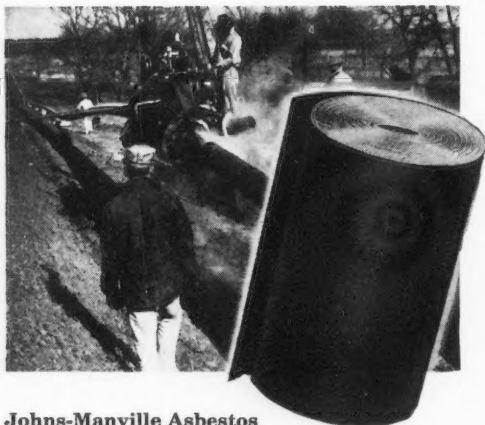
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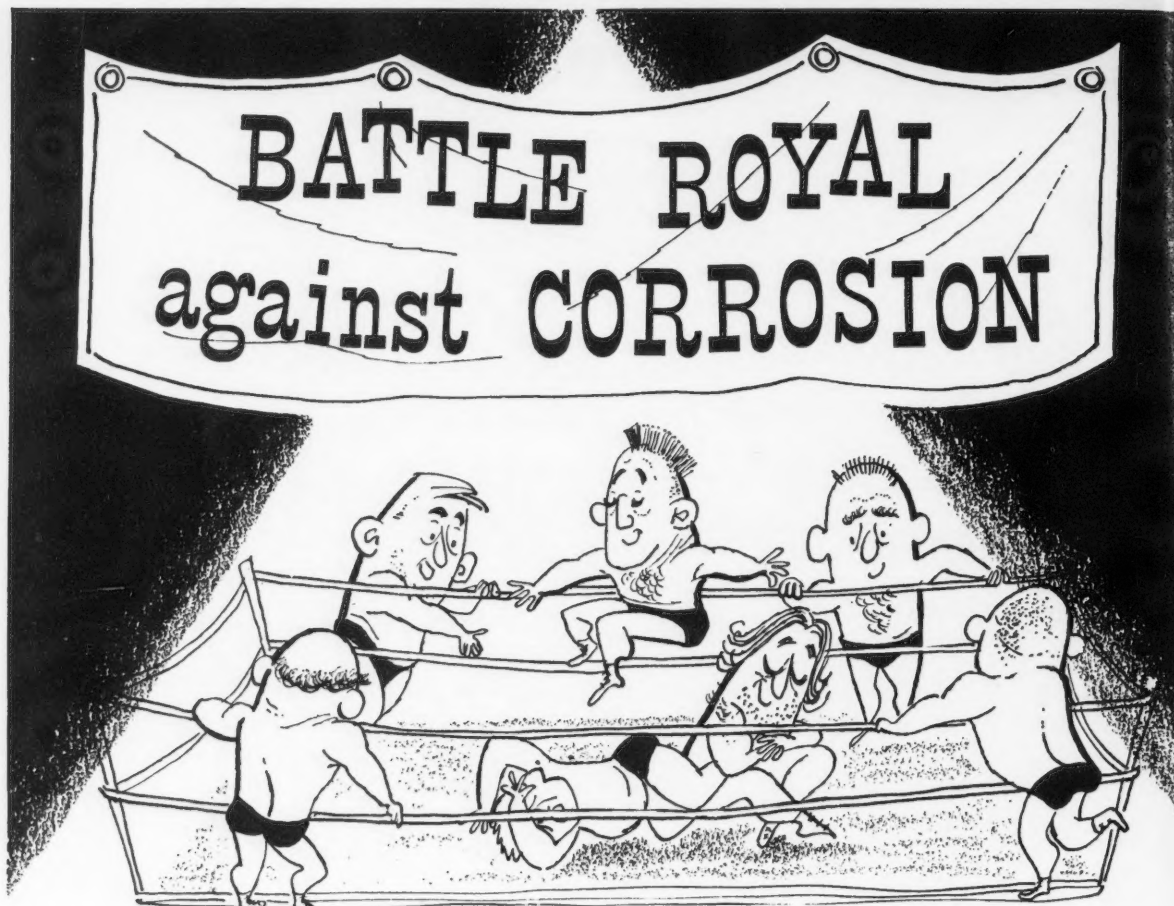
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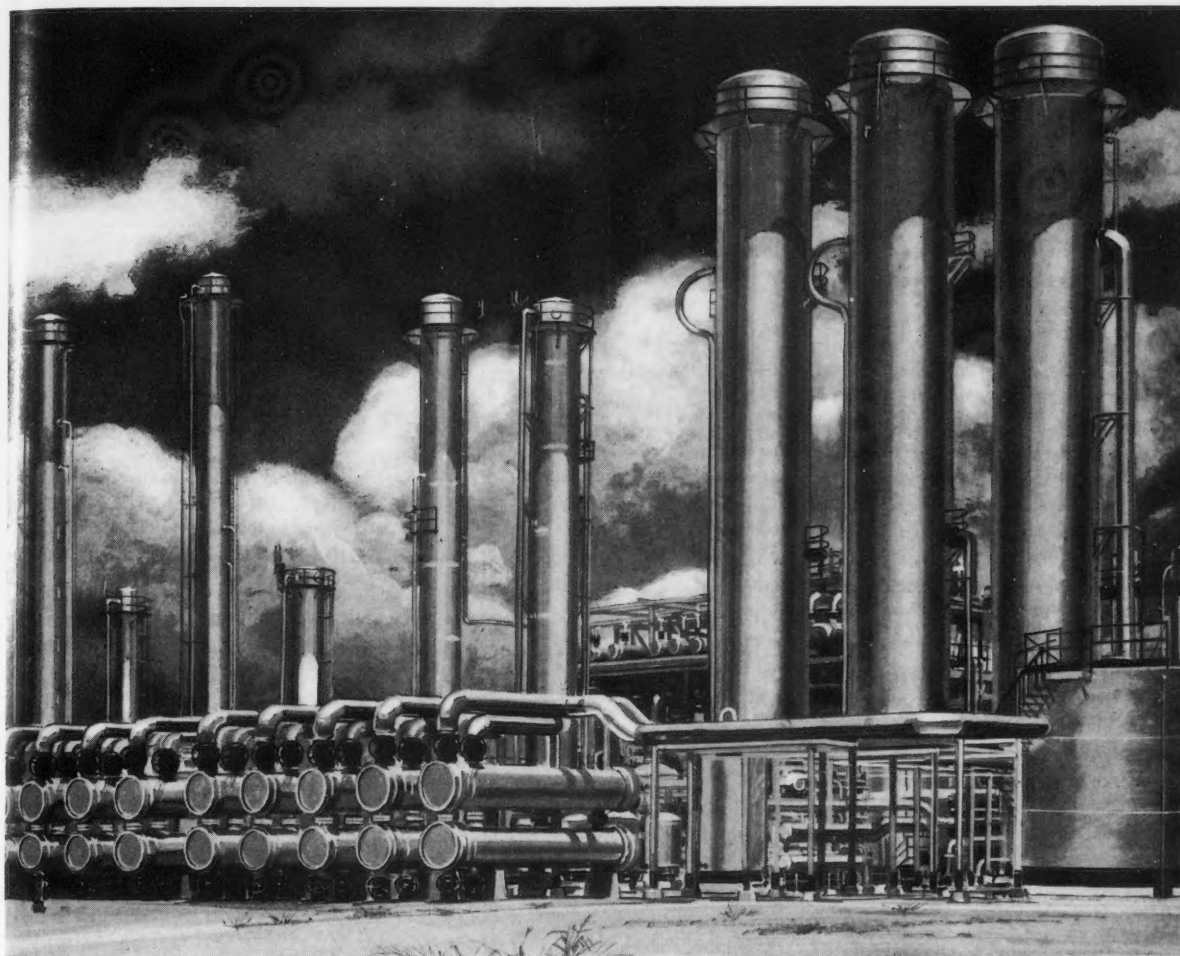
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Plastic Flow of Iron Oxides And the Oxidation of Iron*

By J. D. MACKENZIE⁽¹⁾ and C. E. BIRCHENALL⁽²⁾

Introduction

IN THE COURSE of studying the oxidation kinetics of iron at high temperatures, attempts were made to prepare wüstite specimens by the reaction of iron parallelepipeds with pure oxygen. At weight gains corresponding to the desired compositions, the oxidation was terminated and homogenization in argon carried out for long periods. On sectioning, the resulting wüstite specimens invariably contained a rectangular central box-like cavity.¹ Samples from oxidation at 800-850 C gave cavities with walls of very sharp edges and corners and with dimensions exactly identical to those of the original iron specimens (see Figure 1). On increasing the temperatures of oxidation stepwise to 1050 C, the sizes of the cavities were seen to undergo a gradual decrease, their shapes becoming less well-defined. However, in wüstite specimens prepared by the oxidation of iron with a hydrogen-water vapor mixture whereby the formation of magnetite and hematite is excluded, this cavity is not observed. This effect of the oxidizing medium on the form of the wüstite specimen is illustrated in Figure 2. It is seen that although some porosity is present in one sample, the box-like cavity clearly shown in the other sample is absent.

It is indicative therefore that the formation of the cavity may be associated with the presence of the two higher oxides and possibly with their plastic properties. During the oxidation in a hydrogen-water vapor atmosphere, the formation of vacancies and subsequent porosity caused by the transport of iron ions outwards may be compensated by the inward migration or "creep" of the wüstite layer, thus resulting in a solid homogeneous oxide. In the oxygen

Abstract

Under certain conditions, the oxidation of iron in oxygen at high temperatures is accompanied by the formation of a central box-like cavity the dimensions of which are identical to those of the original iron specimen. The decrease in size of this cavity with increasing temperature and its disappearance when the formation of magnetite and hematite is excluded by a controlled oxidizing potential indicates that the plastic properties of the oxides may be an important factor. This is qualitatively confirmed by the measurement of the relative plasticity of the three oxides at 800-1000 C in a specially designed apparatus. 3.2.3

oxidation, however, the wüstite layer is at every instant in contact with a layer of magnetite which is in turn adjacent to a thinner layer of hematite. It is possible that either or both of these higher oxides form a non-plastic cage which prevents the movement of the wüstite inward thus causing the formation of the observed central cavity.² The present plasticity measurements therefore were undertaken to obtain direct confirmation on this hypothesis.



Figure 1—Box-shaped cavity from the O₂ oxidation of iron at 850 C. Tube in the center is caused by hole drilled to receive the platinum suspension wire.

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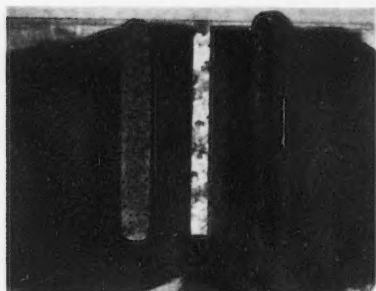


Figure 2—Effect of oxidizing medium on the form of wustite specimens. Samples, left to right, are as follows: solid wustite from H_2/H_2O oxidation, original iron specimen, and wustite with cavity from O_2 oxidation.

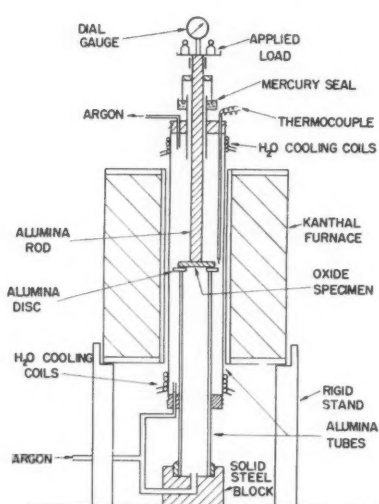


Figure 3—Plasticity apparatus for measurements in controllable atmospheres at high temperatures.

Experimental Method

Because of the very great experimental difficulties involved in the preparation of single crystals of the oxides of iron, polycrystalline materials were used in this investigation. Although the results may be subjected to errors associated with grain-boundary effects, a qualitative measure of the relative plasticity is obtainable, especially as polycrystalline materials are actually involved in the formation of the box-shaped cavity. Wüstite specimens were prepared from the oxidation of Armco iron parallelepipeds, $\frac{3}{4}$ -inch \times $\frac{1}{4}$ -inch \times $\frac{1}{16}$ -inch in dimension, in a controlled hydrogen-water vapor atmosphere. The experimental details of this procedure will be described elsewhere.³ Magnetite was prepared by the oxidation of similar iron blanks in argon-steam mixtures. Hematite specimens sintered from powder were supplied by the RCA Research Laboratories. All the samples were hand polished to 600 emery paper until the final dimensions of the parallelepipeds were 2 cm \times 0.7 cm \times 0.2 cm.

No extensometers are recorded in which plasticity

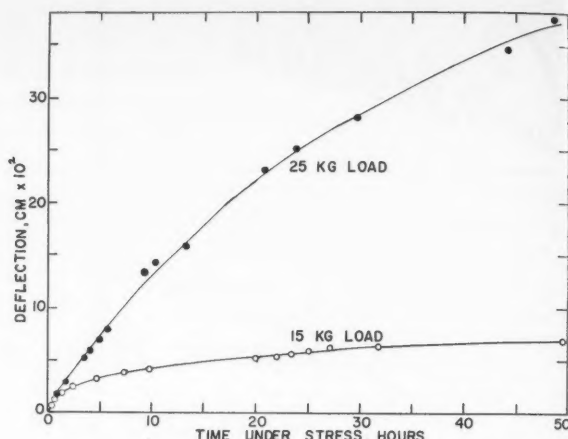


Figure 4—Creep of polycrystalline wustite at 900 C.

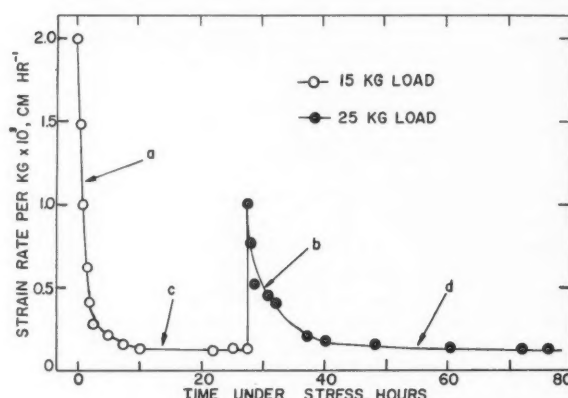


Figure 5—Effect of plastic deformation of wustite at 900 C under varying loads.

measurements may be carried out in a controllable ambient atmosphere at high temperatures on small samples of simple shape. The apparatus shown in Figure 3 was developed therefore for the present work. The oxide specimen was placed on an alumina disc which had a 1.5 cm diameter hole in the center. The disc in turn rested on an alumina tube rigidly mounted on a solid steel block. Stress was applied by placing weights on a pan connected to the central alumina rod, 1 cm in diameter. The mercury seal permitted vertical movement of the rod and yet maintained the inert atmosphere in the apparatus. A Kanthal furnace was used and the temperature was accurately controlled by a Celestray potentiometric-type controller via a Chromel-Alumel thermocouple in contact with the heating element. Temperature measurements were made by a standardized Chromel-Alumel thermocouple with the hot junction placed adjacent to the sample. Deformation of the specimen was measured by the downward movement of the alumina rod indicated by the dial gauge sensitive to 0.0001 inch in contact with the pan.

After the specimen was placed over the alumina disc, the alumina rod was inserted until the end was

about 1 cm from the surface of the sample. The apparatus was then sealed and purged for 12 hours with argon, at the end of which the furnace was switched on. When the steady required temperature was reached, the alumina rod was lowered until it rested on the oxide specimen. Weights were then added to the pan and the deformation followed by the dial gauge.

Results

Plastic deformation of wüstite (23.7 weight percent O_2) was noticeable at 800 C when the applied load was 10 kilograms, the thickness of the oxide being 0.2 cm. The creep curves of two specimens at 900 C under different stresses are shown in Figure 4. They are similar in form to creep curves observed for metallic specimens. A typical creep rate-time relationship is shown in Figure 5, where the creep rates resulting from two different loads are reduced to the same scale for purpose of comparison. The initial high rate observed falls rapidly with time and assumes a constant value over long periods. In Figure 6 an initially straight wüstite specimen is shown to have undergone creep after four days at 900 C under an applied force of 25 kg. In addition to this bending, a slight indentation also was caused by the alumina rod which was found to be embedded lightly in the wüstite after an experiment. No corrections were made for the creep of the alumina which is only slightly plastic at 1200 C, the ultimate tensile strength being 1690 kg per cm^2 at 1000 C⁴. Up to 1000 C, both magnetite and hematite exhibited no creep even when the load was increased to 40 kg, this being the upper load limit of the present apparatus. The maximum shear stress in kg per cm^2 on the specimens in this arrangement is about four times the load in kg.

Discussion

When a polycrystalline oxide containing some porosity is subjected to compression, two effects will be expected. First of all, sintering will occur resulting in a denser material. This is clearly shown in parts (a) and (b) of Figure 5 where the rate drops rapidly within a relatively short period, and also supported by the observed indentation made by the alumina rod. Secondly, for a certain applied load, there is a limit to the extent of this sintering, after which any observed deformation will be primarily creep and the rate is expected to be constant. This is shown by part (c) in the figure. When the applied stress is increased after a constant creep rate has been reached for a particular stress, further sintering may occur as evident from the portion (b) of the graph where a load of 15 kg has been suddenly increased to 25 kg. Over part (d), the deformation rate again assumes a constant value and probably is due mainly to creep. It may be noted that over (c) and (d), the creep rates per kg are similar although the actual applied stresses are different.

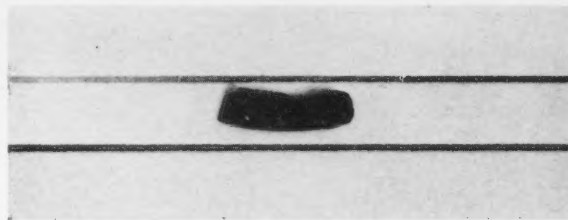


Figure 6—Wüstite specimen (23.2 percent O_2) bent under a load of 25 kg at 900 C for four days.

That creep does occur in polycrystalline wüstite is evident from Figure 6.

At a higher temperature and a much greater stress than those applied in the case of wüstite, creep was not observed for magnetite and hematite. Although no quantitative measure is presently available, it may be concluded that wüstite is more plastic than the two higher oxides of iron over the temperature range 800-1000 C. The formation of the box-shaped cavity is therefore a result of the rigidity of magnetite and hematite.

It is well known that plastic flow occurs much easier in metal oxides having a cubic close-packed structure than those with a hexagonal structure. Thus Wygant⁵ has shown that for polycrystalline MgO and $\alpha-Al_2O_3$, the former is much more plastic. This is attributed to the much larger number of equivalent preferred glide planes and directions in the cubic MgO. Recently,⁶ this was confirmed for single crystals of $\alpha-Al_2O_3$ and MgO. In the case of single crystals of Al_2O_3 , the hexagonal α -form has been found to be much stronger than the spinel α -form at high temperatures.⁷ For two cubic modifications of an oxide, that with the smaller number of equivalent preferred glide directions will be expected to exhibit a less plastic behavior. Thus the spinel Fe_3O_4 should be less plastic than FeO which has the NaCl-type structure and hence the larger number of glide directions. The present observations are therefore not entirely unexpected. Analogous to Al_2O_3 , it is probable that the hexagonal $\alpha-Fe_2O_3$ has a more rigid structure than Fe_3O_4 and is therefore the least plastic of the three oxides of iron.

Acknowledgment

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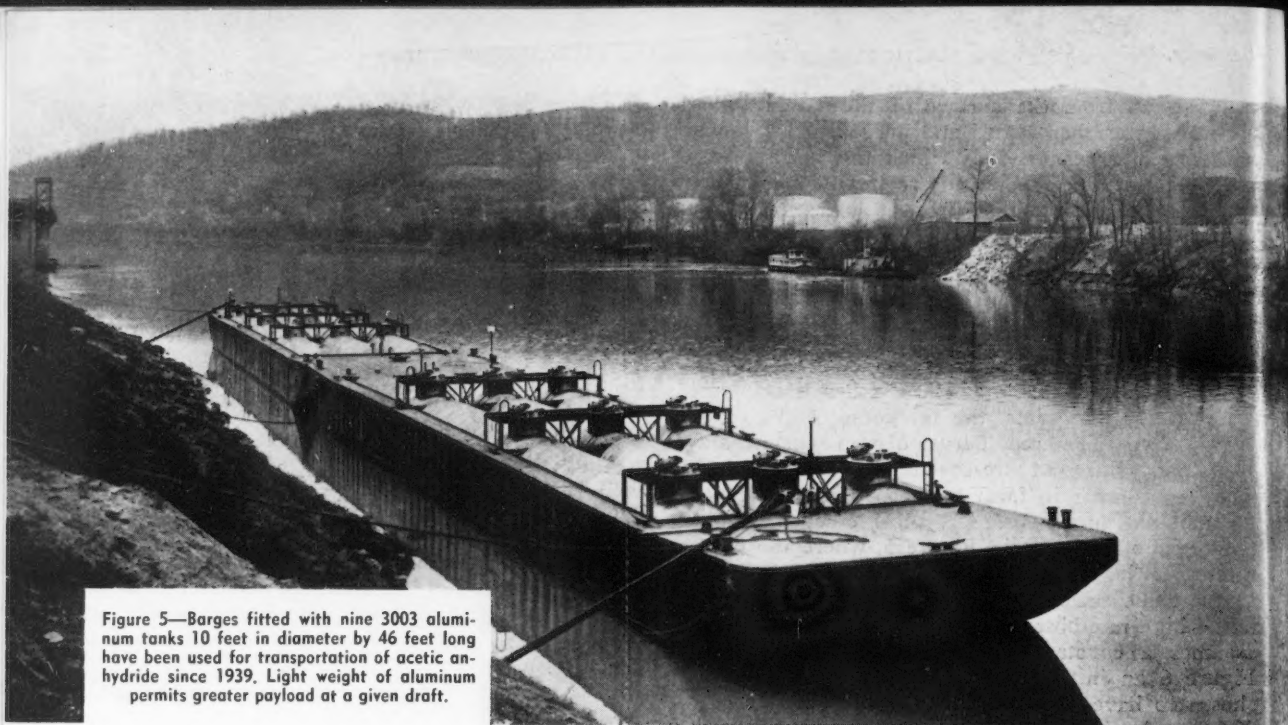


Figure 5—Barges fitted with nine 3003 aluminum tanks 10 feet in diameter by 46 feet long have been used for transportation of acetic anhydride since 1939. Light weight of aluminum permits greater payload at a given draft.

Using Aluminum Alloys With Short Chain Aliphatic Acids And Anhydrides*

By A. B. McKEE and W. W. BINGER

Introduction

FOR MANY YEARS the mutual compatibility of aluminum and organic acids has been recognized. Favorable comments on the behavior of aluminum in contact with acetic, butyric and several other organic acids appeared in a book by J. W. Richards, published in 1896.¹ An investigation by Seligman and Williams² in 1916 provided valuable information concerning the action of boiling dehydrated acetic, propionic and butyric acids on aluminum. A paper³ by Poe, Warnock and Wyss in 1935 presented weight loss data for 1100 aluminum alloy in about 20 organic acids, including acetic, propionic and butyric. A more recent paper⁴ by Teeple furnished data on the resistance to corrosion of several metals including aluminum in contact with some organic acids and related compounds. The present paper deals specifically with formic acid and with acetic, propionic and butyric acids and their anhydrides.

Factors Affecting Choice of Materials

Selection of a material of construction in the chem-

Abstract

The suitability of aluminum for handling low molecular weight fatty acids and anhydrides for temperatures up to about 50 C has been demonstrated by extensive laboratory tests and confirmed by actual service experience for over 30 years. At the boiling temperature aluminum is highly resistant to acetic, propionic and butyric acids containing from about 0.2 or 0.3 percent to 1 or 2 percent water, but not to solutions containing higher or lower amounts of water. These acids, anhydrides and their mixtures have been processed, stored or shipped in aluminum storage tanks, heating coils, drums, tank cars, piping, valves, stills, heat exchangers and reaction vessels. In addition to excellent resistance to corrosion, aluminum equipment has an added advantage in that it does not contaminate these products nor alter their water-white appearance.

4.4.2

ical industries is based on a number of factors, such as the service life of the equipment, cost and the effect of the material on the chemical product it contacts. In selecting a material for a given application, there frequently is a dominant characteristic that is essential to satisfactory performance. Hence, the material will be chosen with primary consideration of that characteristic and the best possible compromise is made with the other desirable characteris-

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tics. Some favorable characteristics of aluminum are high resistance to corrosion, nontoxicity, maintenance of water-white appearance of the product, good heat conductivity, availability, formability, weldability, light weight and adequate strength. The composition of a few of the corrosion resistant aluminum alloys commonly used for drums, tanks, piping and other chemical applications is given in Table 1.

Laboratory Test Procedure

Specimens, $\frac{1}{16} \times \frac{1}{2} \times 3$ -inch, were completely immersed in quiescent solutions, usually 250 ml contained in 250 ml glass stoppered bottles for the room temperature tests or in 500 ml balloon flasks equipped with refluxing condensers for the tests at 50 C (122 F) and at the boiling temperature. Pure reagents and distilled water were used. Time of tests ranged from 45 minutes to 24 hours for solutions that caused rapid corrosion to 7 days for solutions that had only slight action on aluminum. Time-weight loss tests at room temperature for periods up to 2½ weeks revealed that the weight loss of aluminum in solutions of these acids increased linearly with time. Solutions were not changed during the tests.

After degreasing, surface preparation of the various metals before exposure and prior to weighing was as follows:

Aluminum—etch 20 seconds in 5% nitric—0.25% hydrofluoric acid solution at 95 C (203 F), soak in 70% nitric acid for 5-10 minutes and rinse with water.

Mild Steel—pickle in 10% hydrochloric acid containing 1% Rodine No. 50 for 10 minutes at room temperature and rinse with water.

Copper—scour with Bon Ami and water; rinse with water.

Stainless Steel—degreased only.

After specimens were removed from test, but before re-weighing, they were cleaned as follows:

Aluminum—10 minutes in 5% phosphoric—2% chromic acid at 80-90 C (176-194 F).

Mild Steel and Copper—10 minutes in 10% hydrochloric acid containing 1% Rodine No. 50 at room temperature.

Stainless Steel—10 minutes in 70% nitric acid at room temperature.

Behavior of stainless steel (Type 304), cold rolled mild steel (0.07% C, 0.33% Mn) and copper (electrolytic) was evaluated in one test only. This involved exposure to glacial acetic acid at room temperature and at the boiling temperature (see Table 2). Corrosion rates were calculated from weight loss data.

The dehydrated or anhydrous acids used for this investigation were prepared by bubbling dry air through a solution of the refluxing commercial strength acid, by fractional distillation or by a combination of the two methods. To prevent condensation of water being removed from the acid, air-cooled rather than water-cooled reflux condensers were em-

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W. W. BINGER—Assistant Chief, Chemical Metallurgy Division, Alcoa Research Laboratories, he has been with Alcoa since 1943 and was promoted to his present position in 1953. His principal activity has been in the development of aluminum alloys for chemical industry applications. During 1944 and 1945, while on leave from Alcoa, he was with Manhattan Project at University of Chicago and Oak Ridge, Tenn. He graduated from University of Wisconsin in 1943 with a BS in chemical engineering.

ployed. Actual water content was determined by using the Karl Fischer Reagent.

Formic Acid

The classical method of preparing formic acid was decarboxylation of oxalic acid in the presence of a polyhydroxy compound such as glycerol. Large amounts of formic acid are now produced by react-

TABLE 1
Composition of a Few of the Corrosion Resistant Wrought Aluminum Alloys Commonly Used for Chemical Applications

ALLOY	Nominal Composition Percent Alloying Elements*				
	Cu	Si	Mn	Mg	Cr
1100.....	99.0%	Minimum Aluminum	.....	.....
3003.....	1.2	.....	.....
3004.....	1.2	1.0	.....
4043.....	5.0	.....	.....	.....
5052.....	2.5	0.25
5154.....	3.5	0.25
6061.....	0.25	0.6	.....	1.0	0.25
6063.....	0.4	.....	0.7	.....

* Remainder is aluminum plus impurities.

TABLE 2
Comparison of Resistance to Corrosion of 1100-H14 Aluminum Alloy With Competitive Metals in Glacial Acid.

Alloy	Calculated Volume Loss of Metal Inch ³ /Inch ² /Year	Discoloration of Solution
ROOM TEMPERATURE, 1 WEEK		
1100-H14.....	0.0000	Remained water-white
304 Stainless Steel...	<0.0001	Faint salmon color
Copper.....	0.0065	Dark blue
Mild Steel.....	0.0586	Badly contaminated with red rust
BOILING TEMPERATURE, 89 HOURS		
1100-H14.....	0.0033	Remained water-white
304 Stainless Steel...	0.0392	Intense salmon color
Copper.....	0.0750	Dark blue
Mild Steel.....	0.429	Badly contaminated with red rust

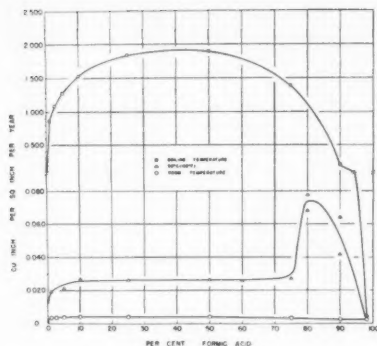


Figure 1—Rate of corrosion as revealed by calculated volume of metal loss for 1100-H14 aluminum alloy in aqueous formic acid solutions.

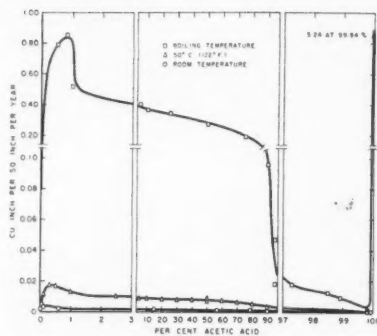


Figure 2—Effect of concentration and temperature on the resistance to corrosion of 1100-H14 aluminum alloy in acetic acid.

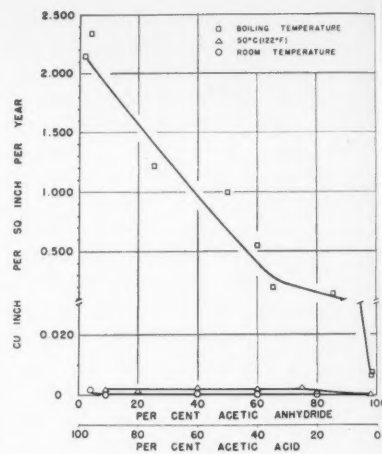


Figure 3—Calculated volume of metal loss for 1100-H14 aluminum alloy in acetic acid-acetic anhydride solutions.

ing an inorganic acid with sodium formate, a by-product from the manufacture of pentaerythritol.

Laboratory Data

Effect of formic acid on the resistance to corrosion of 1100-H14 aluminum alloy is shown in Figure 1. Corrosion rates at room temperature ranged between 0.002 and 0.004-inch³/inch²/yr. for very dilute concentrations up to 98 percent. These rates are comparatively low and indicate good resistance to corrosion. Uniform corrosion was encountered on all the specimens except those exposed to 80-90 percent solutions at 122 F in which case localized etching and edge attack occurred. At the boiling temperature rapid corrosion was encountered at all concentrations except that approaching 98 percent acid.

Service Experience

Although laboratory tests have revealed that aluminum is relatively resistant to chemically pure formic acid at room temperature, formic acid has been handled commercially in aluminum only to a limited extent.⁵ General experience has been that localized corrosion of aluminum occurs because of contaminants such as heavy metal salts in the formic acid. Aluminum equipment is used in the production of aluminum formate.⁶

Acetic Acid And Anhydride

Acetic acid occupies essentially the same position in the field of organic chemistry as does sulfuric acid in the heavy chemical industry. Methods of manufacturing acetic acid can be divided as follows: Fermentation of alcohol, wood distillation and synthetic methods. The major part of the world's production of acetic acid is made by oxidizing acetaldehyde.

Laboratory Data

Behavior of 1100-H14 aluminum alloy in acetic acid solutions at three different temperatures is shown in Figure 2. With the exception of dehydrated

acid at the boiling temperature, maximum rates of attack occurred in dilute solutions. These maximum rates occurred in the neighborhood of 0.06 percent by weight of acetic acid at room temperature, 0.3 percent at 122 F, and 0.8 percent at boiling temperature. At all three temperatures uniform corrosion was encountered. Rates of attack decreased gradually from the maximum, reaching low values for glacial acetic acid. These data indicate that at room temperature low rates of attack are obtained regardless of the concentration of acetic acid.

Glacial acetic acid is marketed as 99.5 percent acid, minimum, and usually contains from 0.2 to 0.3 percent water by weight. Corrosion rates in glacial acetic acid of these water contents were low; even at the boiling temperature the rate of attack was only 0.002-inch³/inch²/yr. However, very severe non-uniform corrosion was encountered at the boiling temperature when water content was reduced. For example, higher rates were found at the boiling point with a water content of approximately 0.05 to 0.08 percent by weight. Fortunately, removal of this last trace of water is difficult. It seems probable that sufficient water normally would be present to prevent dehydration of the acid in most processes. At room temperature no increase in rate of corrosion was noted when glacial acetic acid was dehydrated. Although the rate of corrosion in dehydrated acid was not investigated at 122 F, it is believed that the rate would be of the same order of magnitude as shown in Figure 3 for acetic acid containing low amounts of acetic anhydride at 122 F, i.e., about 0.002-inch³/inch²/yr.

The quality of acetic acid used commercially is such that corrosion difficulties resulting from contaminants in the acid seldom are encountered. In the laboratory the adverse effects of certain contaminants have been demonstrated. For example, 10 ppm of ferric chloride caused significant pitting. Current investigations have demonstrated that the turbid appearance sometimes observed in service with acetic acid has been duplicated in the laboratory under very

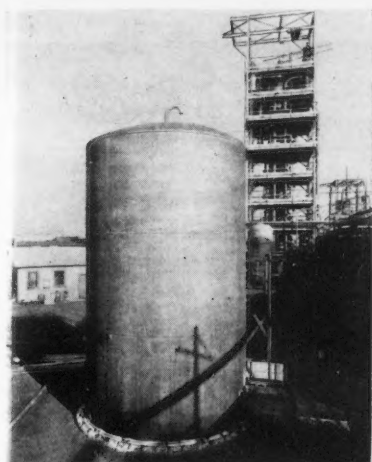


Figure 4—Aluminum storage tank of 15,000 gallons capacity used in storing acetic acid. The riveted 3003 aluminum tank car beside it has been in service since 1930. Aluminum transfer lines are shown also.

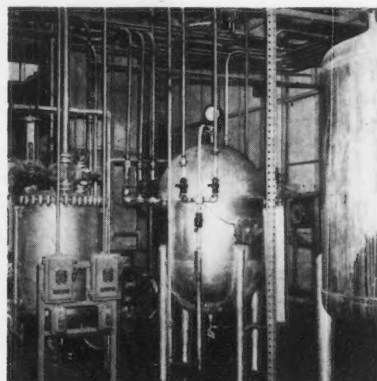


Figure 6—Aluminum reactor used in production of aspirin from acetic acid and salicylic acid. Also shown are aluminum process piping, fittings, ventilation ducts and storage tanks.

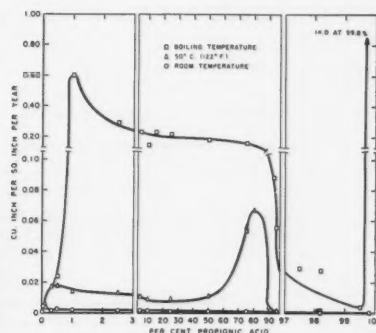


Figure 7—Resistance to corrosion of 1100-H14 aluminum alloy in propionic acid solutions at various temperatures.

specific conditions involving trace amounts of mercury and chloride contaminants and slightly elevated temperature.

A comparison of the behavior of 1100-H14, 3003-H14, 5052-H34, 6061-T6 and 6063-T5 aluminum alloys in acetic acid at various concentrations and temperatures revealed no appreciable differences in resistance to corrosion. The behavior of welded joints was evaluated using welded panels including combinations of 3003-H14, 5052-H34, 5154-H34 and 6061-T6 alloy sheet with 1100, 4043, 5052 and 5154 filler alloys. These were exposed at room temperature to 0.1 percent acetic acid, glacial acetic acid and acetic anhydride. Calculated corrosion rates were of a low order and comparable to non-welded specimens and no evidence was observed of any selective attack at the weld zone.

Superiority of aluminum over other common metals for maintaining water-white acetic acid is demonstrated by the information given in Table 2. Of the four metals evaluated only aluminum caused no visible discoloration of the acid. Corrosion rates shown in this table are lower for aluminum than for the other metals.

In Figure 3 corrosion rates are shown for 1100-H14 alloy in solutions containing various percentages of acetic acid and acetic anhydride. Low rates were encountered for all concentrations at room temperature and at 122 F. Corrosion was uniform at both temperatures. At the boiling temperature, the corrosion rate decreased with increasing anhydride content, reaching a value of 0.007-inch³/inch²/yr. in commercial strength anhydride.

Service Experience

A wealth of service information involving aluminum alloys in the production and handling of acetic acid and anhydride has been accumulated during the past 30 years. The air oxidation of acetaldehyde to acetic acid originally was a batch process carried out

in aluminum lined (1/4-inch liner) steel reactors of about 1000-gal. capacity and equipped with cooling coils for temperature control. The acid (94-95%) from the reactor was then sent to concentrating stills. Also, aluminum condensers have been in service since 1929, handling vapors containing 80 percent acetic acid, 20 percent acetaldehyde and traces of moisture.

In modern installations the oxidation of acetaldehyde is a continuous process. In one plant,⁷ substantial aluminum equipment is used in the production of acetic acid by the oxidation of acetaldehyde. The acetaldehyde is pumped from aluminum tanks to the base of the oxidizers by an aluminum alloy centrifugal pump. The two aluminum oxidizers (3 feet in diameter by 33 feet high) are fitted with aluminum cooling coils. Vapor leaving the oxidizer is recovered in an aluminum condenser. After purification the acetic acid is stored in aluminum alloy tanks.

In the same plant a mixture of acetic acid and acetic anhydride is produced. In this process the acetaldehyde feed is diluted with ethyl acetate in aluminum tanks before entering the oxidizers. Final storage of acetic acid, acetic anhydride and their mixtures is in aluminum.

The "water whiteness" of acetic acid is assured by the use of aluminum equipment. Since 1925, over 450 aluminum alloy tank cars have been fabricated for transporting acetic acid. The alloys include 3003, 3004, 6151, 6061 and more recently, 5052 for greater strength in the welded condition. One of the first aluminum tank cars, a riveted 3003 car, included in Figure 4, is still in glacial acetic acid service after 27 years. Aluminum drums of 5052 and 6053 alloys have also been widely used for a number of years in transporting acetic acid. Aluminum storage tanks are employed almost exclusively for the storage of glacial acetic acid. Tanks up to 12,000-gallon capacity have been in service for 30 years. More recently larger field erected storage tanks have been placed in service.⁸

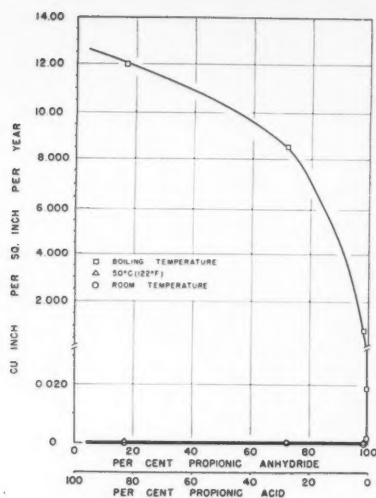


Figure 8—Effect of propionic anhydride additions to propionic acid on resistance to corrosion of 1100-H14 alloy.

A total of 58 aluminum tank cars were built to transport acetic anhydride; 47 of these cars were of 3003 alloy, one of 3004 alloy and 10 of Alclad 2014 alloy. Three barges containing nine large 3003 alloy tanks 10 feet in diameter by 46 feet long have been in service since 1939 for transporting acetic anhydride (Figure 5). Aluminum drums made to Interstate Commerce Commission specifications are also used for shipping acetic anhydride. Storage tanks as large as 17 feet in diameter by 17 feet high have been in service for 20 years at temperatures up to 80 C (176 F).

In processing acetic acid and anhydride to produce products of controlled quality, aluminum offers these specific advantages: (1) high resistance to corrosion, (2) non-toxicity and (3) does not contribute to discoloration of the product. For the purposes of illustration a few examples are cited.⁹

Aluminum kettles have been in use since 1927 in the esterification of glycerol with glacial acetic acid to produce triacetin. Aluminum stills are used also in the vacuum distillation of the triacetin at 170 C.

Raw materials (acetic acid and salicylic acid) of aspirin and the final product are prepared, stored and packaged in aluminum equipment. The aluminum reactor shown in Figure 6 is used in the production of aspirin. Aluminum is also utilized for process piping, fittings, hoppers, ventilators and ducts.

Aluminum tanks, pipe, valves, pumps, reflux condensers, vapor lines, heating coils, evaporators and reaction vessels are used in the production of acetanilide, an analgesic and pharmaceutical intermediate.

The desired degree of transparency of cellulose acetate for production of plastic film is maintained with aluminum process equipment, such as acetylators, aging tanks, precipitators, water extraction tanks, conveyors and rotary driers.¹⁰ In the production of synthetic fibers and textiles, aluminum ducts, hoods and equipment such as spinning buckets, work bobbins, spinning bobbins and numerous reciprocating parts in the weaving and knitting machines are used to reduce

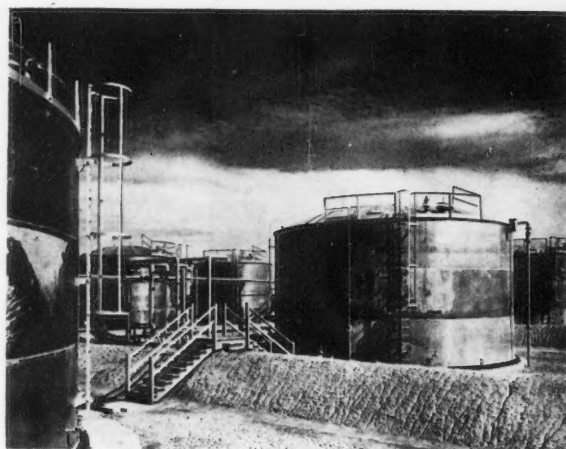


Figure 9—Aluminum tank farm for storage of acetic acid and propionic acid. In foreground are three 120,000 gallon acetic acid tanks. Propionic acid is stored in two 50,000 gallon tanks in the rear.

inertia and to avoid discoloration of cellulose acetate fibers.

Aluminum condensers and piping are employed in the preparation of polyvinyl acetate (Vynlite) because contamination by certain other metals hinders polymerization. The final product is also stored in aluminum.

Propionic Acid And Anhydride

For many years the chief commercial source of propionic acid was as a by-product from hardwood carbonization. More recently the acid has been produced by converting n-propyl alcohol to propionaldehyde and then oxidizing this to propionic acid. Natural gas is also an important source of raw materials used in the production of propionic acid. The Hydrocol version of the Fischer-Tropsch process for synthesizing gasoline from natural gas also yields propionic acid as a by-product. Air oxidation of natural gas hydrocarbons produces n-propyl alcohol and propionic acid.¹¹

Laboratory Data

The effect of temperature and concentration on the resistance of 1100-H14 alloy to corrosion by this acid is shown in Figure 7. These curves generally resemble those of acetic acid, indicating that the effect of the two acids on aluminum is analogous. As with acetic acid, low rates of attack were encountered for all concentrations of propionic acid at room temperature.

One prominent difference between the acetic and propionic acid corrosion curves is that the curve for propionic acid at 122 F passes through two peaks instead of one. A peak in the corrosion rate curve occurs as usual in the dilute range (0.018-inch³/inch²/yr. at 0.5 percent). However, another peak, the maximum (0.055 to 0.065-inch³/inch²/yr.) occurs at 75 to 80 percent concentration. Between these two peaks the corrosion rate drops to a minimum of

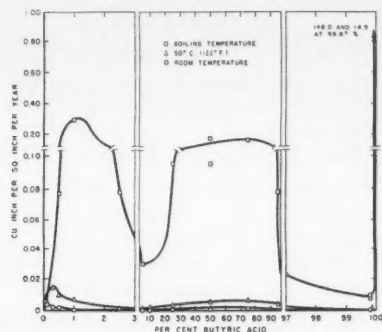


Figure 10—Calculated volume of metal loss for 1100-H14 aluminum alloy in butyric acid solutions.

0.009-inch³/inch²/yr. at 10 percent concentration. At 98 percent acid the attack at 122 F is low (0.0006-inch³/inch²/yr.). The attack was uniform at all temperatures, except for the 75 and 80 percent solutions at 122 F that caused pitting type of attack.

At the boiling temperature the rate of corrosion in commercial strength propionic acid, which had a water content of 1.8 percent, was 0.0275-inch³/inch²/yr. However, after fractionating a sample of propionic acid to a water content of 0.49 percent, the rate of corrosion in this solution at the boiling temperature dropped to 0.0048-inch³/inch²/yr. When this same propionic acid solution was further dehydrated to a water content of 0.2 percent, the calculated rate of corrosion of 1100-H14 alloy markedly increased to 14.0-inch³/inch²/yr. (Figure 7).

Solutions containing various percentages of propionic acid and anhydride (Figure 8) affected the resistance of aluminum to corrosion in much the same way as did acetic acid-acetic anhydride solutions (Figure 3). The most significant difference was that commercial strength propionic anhydride (98.5 percent) caused high rates of attack at the boiling point, whereas, acetic anhydride did not cause severe corrosion of aluminum. However, propionic anhydride that was further purified by fractionation caused only slight corrosion at the boiling temperature. At room temperature the specimens were not visibly affected and at 122 F uniform corrosion with low rates of attack was encountered. Although high rates of attack were caused by acid-anhydride mixtures at the boiling temperature, the corrosion was uniform.

Service Experience

Aluminum and stainless steel are considered to be the most practical materials for processing, storing and shipping of propionic acid.^{12,13} Both the acid and the anhydride have been handled commercially in aluminum storage tanks for at least 15 years at temperatures as high as 80 C (176 F). In addition to storage tanks, such as shown in Figure 9, aluminum drums, tank cars and pipe are used successfully to handle these chemicals.

Butyric Acid And Anhydride

Butyric acid is prepared commercially by the catalytic oxidation of n-butyl alcohol. Butyric acid and

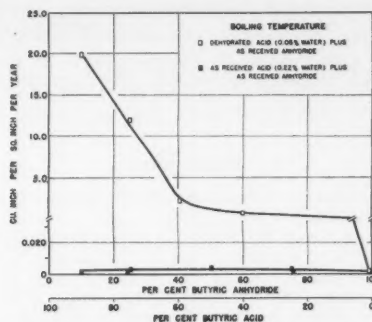


Figure 11—Corrosion rates calculated from volume of metal loss for 1100-H14 aluminum alloy in butyric acid-anhydride solutions.

water formed along with the anhydride are separated by distillation. Aluminum storage tanks and shipping drums have been in service for over 15 years handling both of these products. In addition, aluminum condensers and pipe have been used with butyric acid.

Laboratory Data

Effect of butyric acid on the resistance to corrosion is similar to that of acetic acid and propionic acid, as can be seen by Figure 10. As with the other acids, corrosion rates for any given temperature were higher in dilute solutions than in the more concentrated solutions. However, instead of decreasing gradually from maximum rates of corrosion in dilute solutions, the corrosion rates pass through a minimum at 5 percent acid and then increase again to another peak at approximately 70 to 80 percent. Above this concentration the corrosion rates drop to low values for commercial strength butyric acid containing about 0.2 percent water. It was found that part of this water could be removed readily by fractionation to a point where the acid became extremely corrosive. This dehydrated acid contained about 0.05 percent water and caused the high corrosion rates indicated in Figure 10. Except for this latter situation with dehydrated acid, corrosion was uniform.

Although glacial acetic acid-acetic anhydride mixtures and commercial strength propionic acid-propionic anhydride mixtures caused rapid corrosion of aluminum at the boiling temperature, mixtures of butyric acid and anhydride did not cause rapid corrosion unless the acid was dehydrated prior to mixing with the anhydride. When dehydrated butyric acid (0.05 percent water) was mixed with commercial strength anhydride, high rates were obtained as indicated in Figure 11. Although tests were not conducted with these solutions at room temperature or 122 F, it is not unreasonable to believe that low rates of the same order of magnitude as the rates encountered in either acetic acid-acetic anhydride solutions or in propionic acid-propionic anhydride solutions would be obtained.

Conclusions

Suitability of aluminum for handling short chain aliphatic acids and anhydrides under a variety of con-

centrations and temperatures has been demonstrated by extensive laboratory tests and confirmed by years of service experience. A sound practical installation can best be obtained by taking advantage of all the information and experience that is readily available.

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DISCUSSION

Question by William McGee, Granite City, Ill.:

Has any work been done on corrosion rates of aluminum in hydroxyacetic (glycolic) acid?

Reply by W. W. Binger:

Information in Reference 3 indicates that aluminum exhibits good resistance to corrosion in chemically pure glycolic acid. However, we know of no service applications of aluminum for handling this product because of the substantial amount of heavy metals present in the commercial product.

Question by Howard M. Randall, Amoco Chemicals Corp., Brownsville, Texas:

Have you discovered any contaminant other than mercury which will give a milky appearance to glacial acetic acid?

Reply by A. B. McKee:

No. In our work this milky condition has been observed only under very specific conditions involving trace amounts of mercury and chloride contaminants and slightly elevated temperature.

Question by C. R. Bishop, Metals Research Laboratories, Niagara Falls, N. Y.:

What is the influence of aeration on corrosion of aluminum by acetic and other acids discussed?

Reply by A. B. McKee:

In this work the effect of aeration was not investigated. However, service performance under a variety of conditions over a period of many years indicates that aeration is not a significant factor in the resistance to corrosion of aluminum in these acids.

Any discussions of this article not published above will appear in the June, 1958 issue

DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in *Corrosion* will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies.

Authors of discussions are asked to supply one copy of figures suitable for reproduction and will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of *Corrosion* and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of *Corrosion*, 1061 M & M Bldg., Houston 2, Texas.

The Static Electrode Potential Behavior Of Aluminum and the Anodic Behavior of the Pure Metal And Its Alloys in Chloride Media*

By E. M. KHAIRY and M. KAMAL HUSSEIN

Introduction

INVESTIGATIONS OF the electrode potential behavior of aluminum in buffer solutions initially free from the metal ions reveal the existence on the electrode surface of an inhibitive pre-immersion oxide overlaid with an oxygen film which renders it passive. The passivating surface film was shown to resist the activating action of the electrolyte, a tendency which was most strongly in evidence within the pH range 4-8 (the range of stability of the oxide¹). The porosity of the aluminum surface measured by the repetitive oscillographic method shows values as low as $1.8 \text{ cm}^2/\text{cm}^2$ in several other electrolytes.² However, anodic polarization experiments carried out in presence of acid, neutral and alkaline unbuffered solutions containing chloride ions, demonstrate the pronounced corrosive effect introduced by these ions, particularly in acid media. This led the authors to extend their studies on the corrosive action of the chloride ion within the above pH range. The primary objective of this study was to get an insight into the resistance of the pre-immersion oxide to corrosion and the type of attack taking place in such solutions.

For this purpose, the static potentials of spectroscopically pure aluminum are measured in buffer solutions containing varying concentrations of chloride ions within the pH range 4-8. The anodic behavior also is investigated in buffered sodium chloride solutions within the lower and higher concentration ranges, in order to elucidate the specific effect of the chloride ion by following the changes occurring in the double layer capacity and the underlying anodic processes. The latter investigation also is extended in certain aluminum alloys to find out how the behavior is influenced by the presence of such foreign constituents as Cu, Mg, Fe and Si.

Experimental

The electrodes used in this investigation were spectroscopically pure aluminum rods provided by Johnson and Matthey (England). The aluminum base alloys (i.e., Duralumin, "M22" and "SII" alloys) were provided by "Vereinigte-Aluminium-Werke, A. G. Austria." Composition of these alloys is given in Table 1.

Cells and electrodic devices as well as the oscillographic technique are essentially the same as those used in previous investigations.³

* Submitted for publication October 8, 1956.



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Abstract

The electrode potential behavior of aluminum investigated in buffer solutions of pH 4-8 containing varying concentrations of chloride ions, shows that the electrode potential does not respond to variations of pH. It changes linearly with pCl yielding a more or less constant E' value of -0.54 volt. The corroding effect of the chloride ions supposedly is restricted to the adsorption of these ions on the surface and the electrode behaves as one of the second type.

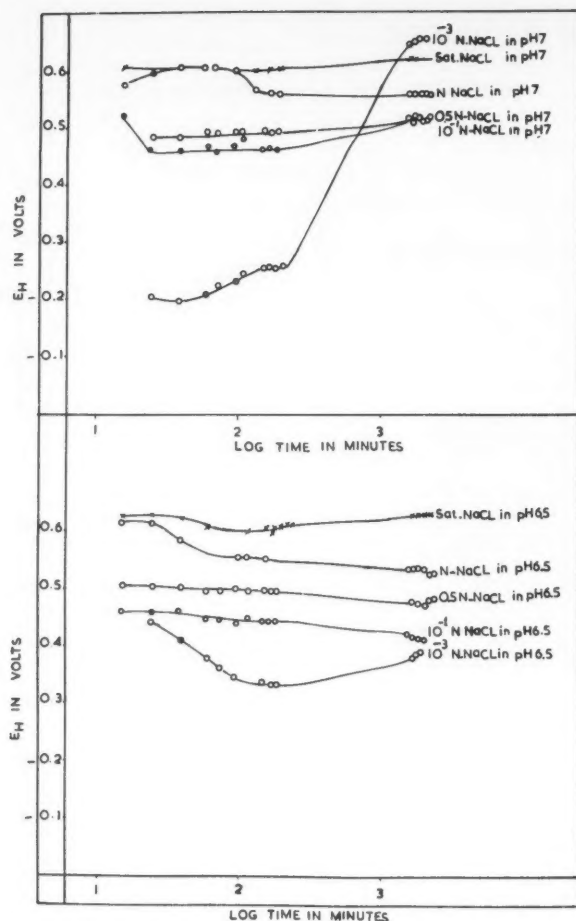
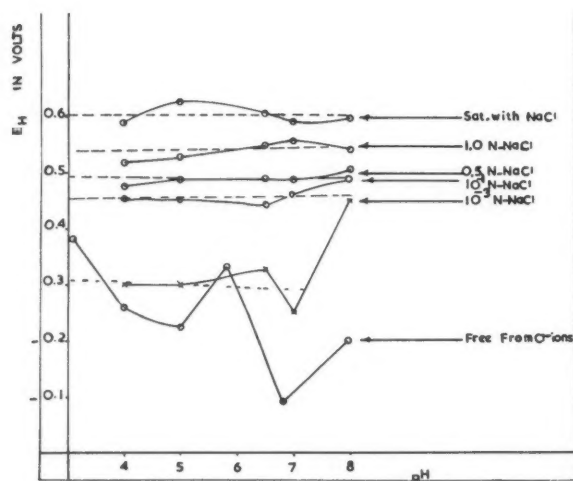
The oscillograms obtained both with the pure metal and with its alloys indicate that the surface oxide resists the corrosive effect up to a $0.1\text{-N } [\text{Cl}^-]$. At higher concentrations, the electrode surface is appreciably activated acquiring relatively high double layer capacities, prominent passivity being achieved only on passing appropriate amounts of electricity.

6.4.2

Results and Discussion

The Electrode Potential Behavior in Sodium Chloride Solutions

The E_h values obtained throughout the pH range 4-8 show only slight variations with time up to the attainment of the steady states (i.e., 1-2 hours from immersion). The steady state values extend over-

Figure 1— E_h -log time curves in buffered NaCl solutions.Figure 2— E_h -pH curves at different $[Cl^-]$.

night except at pH 7 and 8 in the 10^{-3} N solution in which much more negative potentials are acquired (see Figure 1). On the other hand, the potentials obtained in aqueous unbuffered solutions are generally more negative than the corresponding values

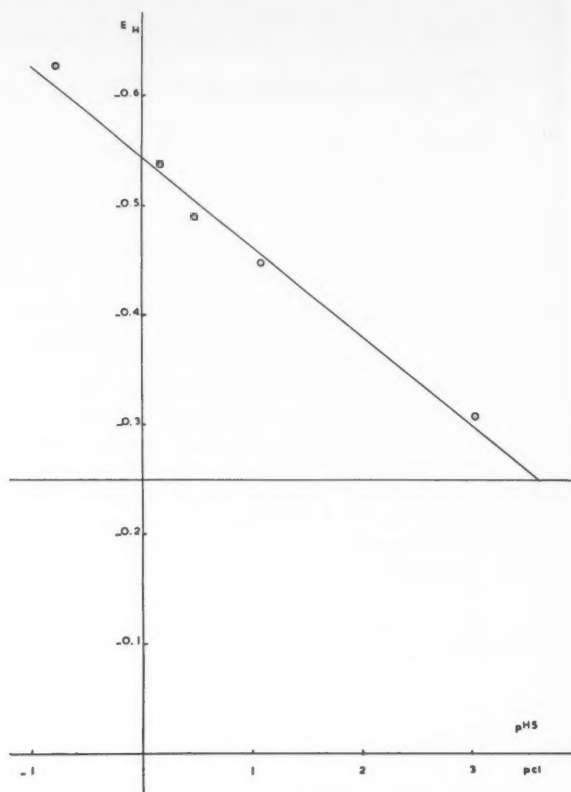
Figure 3— E_h -pCl curve at pH 5.

TABLE 1—Composition of Alloys

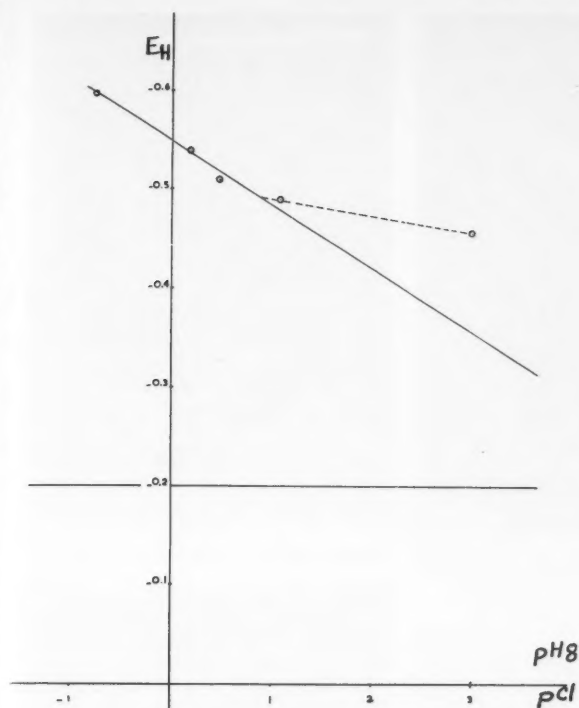
ALLOY	ELEMENT				
	Fe%	Mg%	Si%	Cu%	Al%
Duralumin.....	...	3	...	5	Balance
M22.....	0.3	0.3-0.4	0.5-0.6	..	Balance
SiH.....	0.68	...	12.65	..	Balance

TABLE 2—Extrapolated E' Values

pH	E' (Volts)
4.....	-0.532
5.....	-0.546
6.5.....	-0.546
7.....	-0.546
8.....	-0.548

attained in the buffered solutions. The overnight potentials shift toward more positive values.

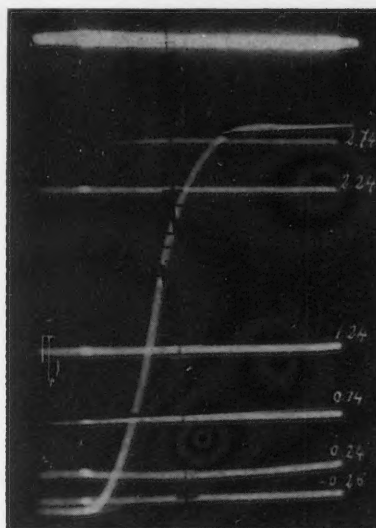
By plotting the first steady state potentials achieved in each buffer solution (from pH 4-8) against pH, within the investigated chloride ion concentration range, the curves shown in Figure 2 are obtained. These curves reveal that down to 10^{-1} N concentration, the electrodes do not respond appreciably to variations of pH. However, the potentials recorded in these solutions approach, successively, with dilution, those attained in the absence of chloride ions. The E_h /pH plot obtained in the 10^{-3} N solution manifests approximately the same behavior as that encountered by the electrode in chloride ion-free solutions.

Figure 4— E_h -pCl curve at pH 8.

In order to investigate the specific effect of the chloride ion, E_h /pCl curves are plotted for each buffer solution. Straight lines can always be traced between the points along the whole pCl range (Figure 3), except at pH 8 where the value corresponding to the highest pCl deviates considerably from the straight line relationship (Figure 4). The E'_0 values obtained by extrapolation (Table 2) are more or less constant approximating a value of -0.546 volt.

The constancy of the E'_0 values as well as the fact that the electrode responds more or less reversibly to variations of pCl, indicate that the electrode behaves in buffered chloride ion solutions as an electrode of the second type. The E_h /pH curves obtained at concentrations higher than 10^{-3} N show that the potential is almost independent of pH within the investigated range, a fact which supports the above view. At lower concentrations, however, the potentials which are more positive varying irregularly with pH may correspond to the system $Al/Al_2O_3/O_2$, as was the case in the absence of chloride ions, indicating the slight corroding effect exerted by these ions at such low concentrations. The behavior in the chloride media may be explained by assuming that owing to their pronounced penetrating power and decided tendency to be adsorbed on the electrode surface, chloride ions are capable of destroying the passive character of the natural oxide film. The attack may take place either on the anodic parts existent in the pores of the oxide or through adsorption on the surface as a first step for its dissolution.

The first type of attack leads eventually to metallic dissolution and subsequently increases the porosity of the electrode surface, a result which was obtained

Figure 5— 10^{-3} N NaCl solutions buffered at pH 4.

by the authors in previous investigations.⁴ A local action cell sets up between the bare metal parts as anode and the adsorbed oxygen adhering to the electrode surface⁵ as cathode. The cathodic reaction is the dissolution of oxygen-yielding hydroxyl ions which react with the anodically produced metal ions with subsequent formation of the oxide within the pores. The presence of chloride ions enhances such a local action process, decreasing thus the over-voltage effect brought about by adsorbed oxygen.

The second type of attack takes place, presumably, after the process of oxidation has been completed through the local action process. The electrode surface may be thought of as a metal/inhibitive oxide/adsorbed chloride ions system, the extent of adsorption being determined by the chloride ion activity and hence the linear E_h /pCl curves. That the mean E'_0 value obtained within the pCl range -0.78 to 3.2 (-0.54 volt) is comparable with the standard electrode potential of the $Al/AlCl_3$ couple (-0.84 volt) suggests that the chloride ions probably are adsorbed on the oxide surface in the ratio $Al:Cl$ corresponding to the formula $AlCl_3$. However, it must be duly recognized that owing to the marked tendency of aluminum chloride to be hydrolyzed in presence of a relative preponderance of hydroxyl ions, the adsorbed layer becomes liable to diffuse away into the bulk of solution with subsequent destruction of the underlying oxide layer. The products of hydrolysis are either basic chlorides or aluminum hydroxide, according to the pCl and to the pH values of the solutions. Within the investigated pH range (4-8), such a behavior is manifested only in the most dilute chloride ion solutions buffered at the pH values 7 and 8, as revealed by the corresponding E_h values.

Inspection of the results obtained in aqueous unbuffered sodium chloride solutions indicate that the corrosion of the aluminum surface is readily achieved in unbuffered rather than buffered solutions, the

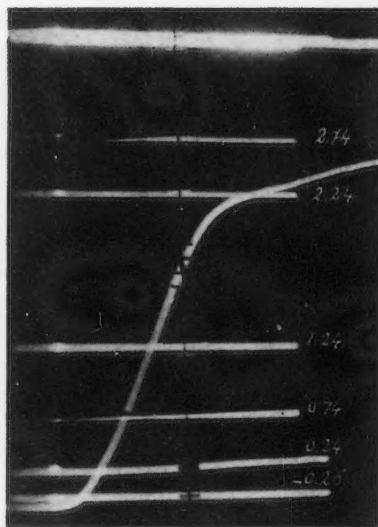
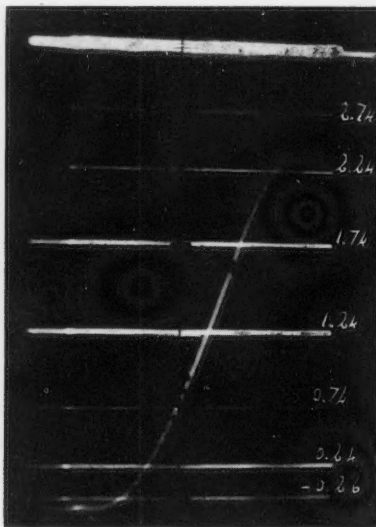
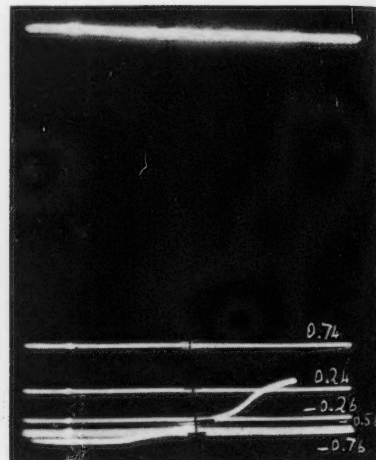
Figure 6— 10^{-3} N NaCl solutions buffered at pH 7.Figure 7— 10^{-3} N NaCl solutions buffered at pH 8.

Figure 8—Saturated NaCl solutions buffered at pH 4.

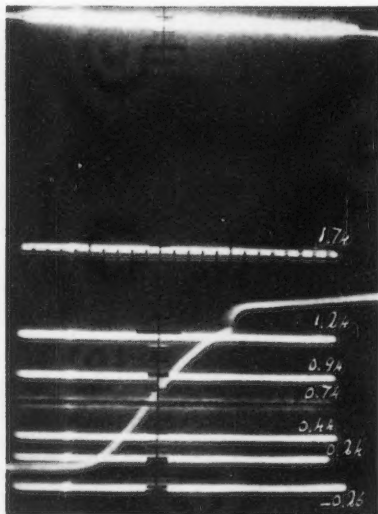


Figure 9—Saturated NaCl solutions buffered at pH 4.

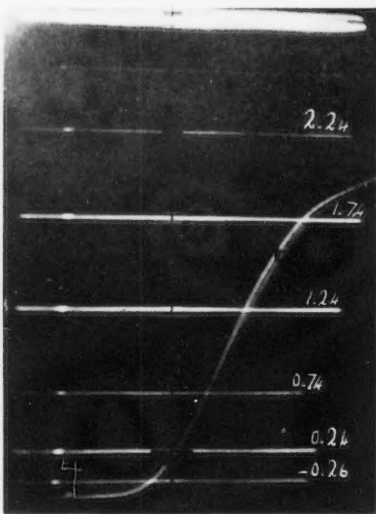


Figure 10—Saturated NaCl solution buffered at pH 7.

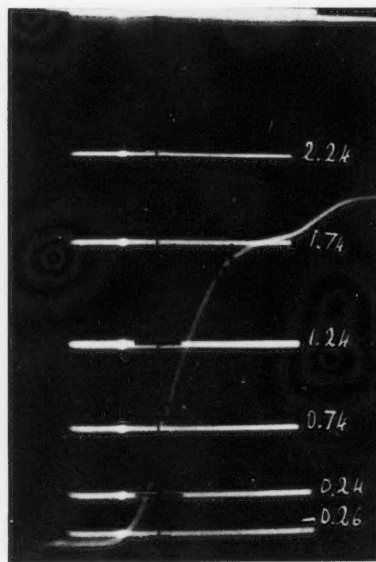


Figure 11—Saturated NaCl solution buffered at pH 8.

potentials recorded in the former being much more negative than those in the latter media. In contrast to the behavior in buffered solutions, chloride ions which come into access to the electrode surface bring about the partial dissolution of the natural oxide with the formation of hydroxyl ions, levelling-up the pH value of the solution in the vicinity of the electrode surface. This process which is somewhat hampered by the buffering action of the other type of electrolyte, enhances the process of hydrolysis. The corrosion of the electrode surface shifts the potential towards more negative values.

The Anodic Behavior Of Aluminum And Aluminum Alloys In Sodium Chloride Solutions

The Behavior of Spectroscopically Pure Aluminum

The oscillograms obtained with the spectroscopi-

cally pure aluminum electrode in 10^{-3} N sodium chloride buffered at the pH values 4, 7 and 8 are shown in Figures 5, 6 and 7, respectively, whereas the curves depicted in Figures 8, 9, 10 and 11 are obtained in saturated solutions buffered at the same pH values. Each oscillogram can be subdivided generally into three main parts. The first domain occurs at a rather constant negative potential. The quantity of electricity consumed along this part is attributed to the desorption of any hydrogen formed during the cathodic passage of the repetitive current owing to the activation of the surface. The second domain in these curves corresponds to metallic dissolution with subsequent charging of the double layer and the third domain comprises all the possible stages of oxidation occurring prior to gas evolution.

The curves obtained in the 10^{-3} N solutions were

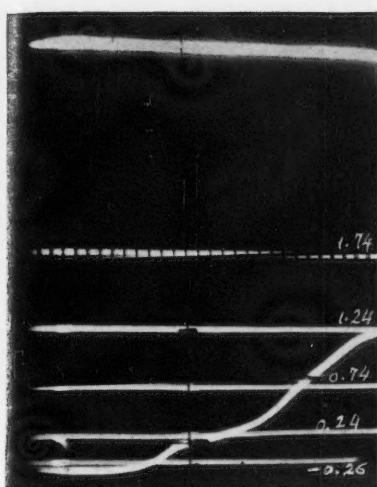


Figure 12—Duralumin alloy in N-NaCl solution.

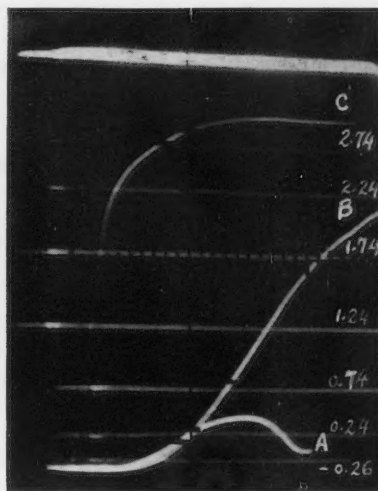


Figure 13—M22 alloy in 1, 0.1 and 0.01 N NaCl solutions.

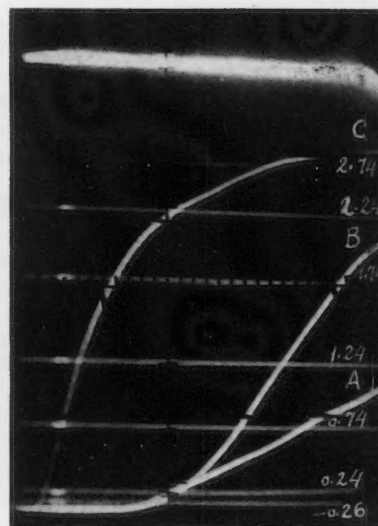


Figure 14—SII alloy in 1, 0.1 and 0.01 N NaCl solutions.

taken at the polarizing current densities 12, 11.9 and 13 ma/cm^2 using a 1 μF condenser in each case to supply the requisite amounts of electricity. All these oscillograms are characterized by considerable potential jumps to more negative values, indicating the rapid attainment of passivity and the slight activating effect introduced by the chloride ion in such dilute solutions. The capacity of the double layer as computed from the slope of the more or less linear build-up of potential associating the charging of the double layer, amounts to 19, 20 and 30 $\mu\text{F/cm}^2$ of the apparent surface area at the pH values 4, 7 and 8, respectively. The onset of prominent passivity is revealed by the high oxygen evolution potentials which vary from ~ 2.7 -2.9. The comparatively greater double layer capacity obtained at pH 8 may be ascribed to the activating effect of the hydroxyl ions, presumably enhanced by anodic polarization.

The curves obtained in the saturated solution buffered at pH 4 (Figures 8 and 9) were taken, successively, at 11.3 ma/cm^2 with a cathodically prepolarized electrode and at 9 ma/cm^2 with an untreated electrode. In these and the other two curves obtained at pH 7 and 8, a 1 μF condenser was utilized in conjunction with the thyatron valve. Curve 8 demonstrates clearly the corroding action of the chloride ion which is materially enhanced through cathodic prepolarization. This could be determined both from the high capacity of the double layer amounting to 153 $\mu\text{F/cm}^2$ and from the relatively low potential acquired by the electrode at its third domain (~ 0.3 volt).

The underlying anodic process most probably is restricted to metallic dissolution with subsequent precipitation of an oxychloride, a process which takes place presumably along the stage extending over the potential range -0.26 to 0.24 volt. Alternatively, passivity is achieved with the untreated electrodes even at a lower current density as shown by the sharp potential shift towards chlorine evolution which

occurs at ~ 1.5 volt. The capacity of the corresponding double layer is comparatively small, amounting to 41 $\mu\text{F/cm}^2$. However, the latter value is higher than those attained in the dilute solutions and in the absence of chloride ions.

The behavior encountered at pH 7 and 8 (Figures 10 and 11) seems to be of special interest. Pronounced passivity is readily achieved and the curves show remarkable potential jumps by the time the double layer has been charged. The capacity of the double layer amounts, respectively, to 33 and 29 $\mu\text{F/cm}^2$ and gas evolution occurs at a relatively high potential of ~ 2 volt. This behavior may be explained on the premise that around the neutral point, the chloride ion does not contribute appreciable activating effect on the electrode surface as it does in acid and strongly alkaline media. One may recall in this respect the results of the static potential measurements in chloride media. These measurements reveal the existence of an adsorbed layer of chloride ions on the surface of the inhibitive oxide film with the electrode behaving as one of the second type towards variations of pCl. It seems that the same behavior predominates at pH 7 and 8 on anodic polarization. The adsorption of chloride ions on the surface of the passive oxide manifests itself by the regular potential rise occurring prior to chlorine evolution from ~ 1.7 to 2 volts.

The Behavior of Aluminum Alloys

Figure 12 contains the oscillogram representing the behavior of the Duralumin alloy in N-sodium chloride. This curve was taken at 9.3 ma/cm^2 together with a 1 μF condenser. The stage corresponding to the desorption of hydrogen consumes a considerable quantity of electricity indicating the relative activity of the electrode surface in that electrolyte. The corroding effect introduced by the chloride ion also is substantiated by the value of the

double layer capacity which amounts to $59 \mu\text{F}/\text{cm}^2$, as computed from the slope of the corresponding charging stage.

The second domain constitutes a well defined stage which may be ascribed to the precipitation of an aluminum hydroxide layer through the interaction of aluminum ions released by metallic dissolution with hydroxyl ions in the vicinity of the electrode surface. Any oxychloride formed by the action of chloride ions on the pre-immersion oxide supposedly is hydrolyzed into the hydroxide. The process of precipitation renders the electrode surface inhibitive and passivity is temporarily attained. This makes up for the gradual potential shift occurring towards gas evolution along the potential range ~ 0.75 to 1 volt, a stage to be ascribed to the adsorption of oxygen prior to its evolution at 1.24 volt.

The oscillogram shown in Figure 13 contains three curves "A", "B" and "C" which represent the behavior of the "M22" alloy in 1, 0.1 and 0.01 N sodium chloride solutions, respectively. The applied current densities were, successively, 12, 11.5 and 13 ma/cm^2 using a $1 \mu\text{F}$ condenser in each case. Curve "A" shows a rather extended stage along its first domain followed by a potential rise up to ~ 0.4 volt. The latter potential remains almost constant until appropriate amount of electricity is passed whereupon it manifests a sharp fall towards more negative values. Such a behavior may be explained by assuming that after the double layer has been fully charged, a detachable salt layer is formed which diffuses away into the bulk of solution on passing the requisite amounts of electricity. This layer is most probably of aluminum oxychloride formed through the attack exerted by chloride ions at the surface oxide. The ease with which the layer is dissolved away rendering the electrode surface active, indicates that the formation of an inhibitive layer of aluminum hydroxide is relatively hampered, in contrast to the behavior of the Duralumin alloy where passivity is achieved.

Alternatively, curves "B" and "C" reveal pronounced passivity which becomes more enhanced as the concentration of the chloride ion becomes lower. That the corroding effect introduced in chloride media decreases appreciably with dilution may be ascertained from the values of the capacity of the

double layer which amount to 72, 45 and $6 \mu\text{F}/\text{cm}^2$ for curves A, B and C, respectively. This is further substantiated by the much higher oxygen evolution potential acquired in the 0.01-N solution amounting to 3 volts as compared with ~ 2 volts attained in the 0.1 N solution.

The behavior of the "SII" alloy is essentially the same as that of the "M22" alloy inasmuch as passivity is readily attained in the dilute rather than in the more concentrated solution. This is clearly observed in curves "A", "B" and "C" (Figure 14) which were obtained at 9.5, 11 and $15 \text{ ma}/\text{cm}^2$ together with a $1 \mu\text{F}$ condenser in each case. However, in curve "A", the potential extends up to gas evolution at ~ 1 volt showing that the surface has been rendered passive through an anodically precipitated hydroxide layer, a process which takes place presumably along the potential range ~ 0.4 -0.7 volt.

Curves "B" and "C", on the other hand, manifest sudden potential jumps associating the charging of the double layer, attaining oxygen evolution at ~ 2 and 2.9 volts, respectively. Passivity supposedly is achieved in the 0.1 N solution through the precipitation of aluminum hydroxide within the pores of the natural oxide, whereas the chloride ion does not seem to cause any destructive effect on the surface film as revealed by the relatively low value for the double layer capacity which amounts to $7 \mu\text{F}/\text{cm}^2$. The attack brought about by chloride ions in the 1 and 0.1 N solutions during the initial stages of the anodic process reveals itself in the higher double layer capacities of 22 and $20 \mu\text{F}/\text{cm}^2$ for curves "A" and "B" respectively.

In conclusion, it may be stated that the pre-immersion oxide film persisting on the surface of aluminum resists the corroding effect of the chloride ion in neutral media up to a 0.1-N concentration.

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Any discussions of this article not published above
will appear in the June, 1958 issue

NACE TECHNICAL COMMITTEE REPORT

A Concentrator For Coordinated Corrosion Testing

A Contribution to the Work of NACE Technical Unit Committee T-4B on Corrosion of Cable Sheaths,⁽¹⁾
By Oliver Henderson⁽²⁾ and Louis Horvath⁽²⁾

Introduction

IN CITIES which have electric railway operation, corrosion problems frequently involve the underground structures of various public utilities. Such mutual problems are electrically interdependent and are best approached on a joint field test basis so that the final solutions decided upon will be acceptable to all the parties concerned. Because of the variations in traction load, stray earth currents encountered in such tests often have significant fluctuations (i.e., sometimes as many as one hundred fluctuations per minute.) It follows that it is necessary that the readings taken at all of the test points set up by each public utility be taken simultaneously. Obviously, this may be difficult to accomplish because it may be necessary to explore 15 or 20 voltage relationships that may be involved at any one location.

In the past, the task has been undertaken by assembling as many acceptable meters and as many people to read the meters as there were test points to be observed. At the call of "read," all observers attempted to read their respective meters at the same instant. However, the ballistics of the various meters and the reaction times of the various observers make it highly doubtful that simultaneous readings actually were ever achieved. Individual tests often had to be repeated because of the failure of one of the observers to read. Because of the difficulty in securing sufficient personnel and in locating suitable meters, the number of possible test points which could be observed was restricted to a bare minimum. In many instances, the number of points tested was too small to give a complete story.

The problem recently took on special importance in Cleveland with the addition of four mercury-arc rectifier substations to the 600-volt DC network of the Cleveland electric railway system. There was also a redistribution of the traction loads in the existing 13 older

Abstract

A concentrator for coordinated corrosion testing is described with which 19 simultaneous voltage readings can be made and which requires only one suitable voltmeter.

The test box contains nineteen 4 mf capacitors, each of which accepts a charge from one of the external test circuits. At the desired instant of testing, the external circuits are all disconnected from the capacitors by the opening of gang-type relays. The voltage standing on each capacitor is then the corresponding voltage of the particular external circuit at the instant of disconnection. By means of a rotary switch, these voltages can be taken off in sequence and read out on a suitable external voltmeter at the convenience of the observer.

The advantages derived from the use of the test box are as follows: (1) One meter observer can duplicate the work of up to nineteen observers on a meter-per-circuit basis;

(2) One accurate voltmeter, having a high input impedance, can be selected for use rather than using an assemblage of 19 meters; (3) Despite fluctuation in measured voltages, the data obtained are more accurate than ordinarily can be obtained by direct readings of a meter on a test circuit; (4) The readings are truly simultaneous; (5) The use of one observer and one meter avoids variances formerly introduced by human characteristics and meter dissimilarities.

4.5.3

substations. It became necessary for all the utilities having involved underground structures to establish and adjust new stray current drainage connections or bonds into the four rectifier substations and to rearrange and readjust the existing drainage connections into the negative bus-bars of the older substations.

Description of Concentrator

As a result of the above situation, a concentrating test box, as shown in Figure 1, was devised and built by the authors to facilitate the tests. Nineteen pair of binding posts were arbitrarily provided to terminate 19 external pair of test leads to as many test points. These test points were located on such structures as water pipes, gas mains, underground power cables, telephone cables, earth, and rails.

Provision is made for a suitable external voltmeter. Because only one



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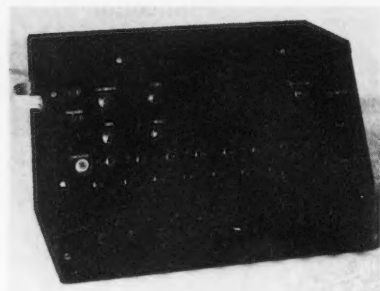


Figure 1—Concentrator for coordinated corrosion testing.

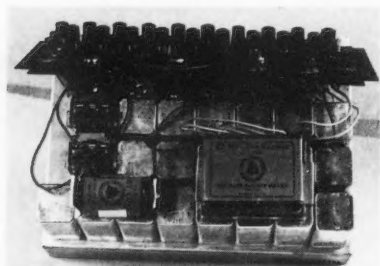


Figure 3—Top view of equipment with cabinet removed.

meter is required it is possible to obtain the optimum type of meter for a given test. Furthermore, there is a distinct advantage in making all tests with the same meter so as to avoid differences in ballistics.

The cabinet measures $8\frac{1}{2} \times 13 \times 8$ inches, weighs 19 pounds and has two handles for a one-man carry. It is powered with dry-cell batteries. This type of power is used because 115-volt AC commercial power often is unavailable at outdoor locations selected for field tests.

Figure 2 is a schematic of the circuitry of the test box. The heavy lines show the test path for only one external circuit. Actually, this path is duplicated for a total of 19 test circuits. This is the number of circuits considered adequate for a test set-up of ordinary complexity. The light-weight lines indicate equipment is common to all of the test circuits.

Relay 1 and Relay 2 are identical wire-spring relays having twelve sets of contacts each. They operate in unison to give the required total number of circuit closures. Both relays have 2500 ohm windings and each requires only 7.8 ma from a 24 volt battery to operate. The relay contacts are enclosed in a dust shield and the relay construction is sufficiently rugged to be suitable for transport and field use.

Closing these two gang-type relays connects each of the nineteen 4 mf capacitors to its respective external test circuit. The voltage assumed by each capacitor will be the same as the test voltage on the leads to which it is connected. This voltage as stored in the capacitor will follow any potential fluctuations that may be impressed. At the desired instant of test, the momentary contact push button (S5) is depressed, which releases the gang-type relays, thereby disconnecting the 19 capacitors. The voltage existing at the instant of

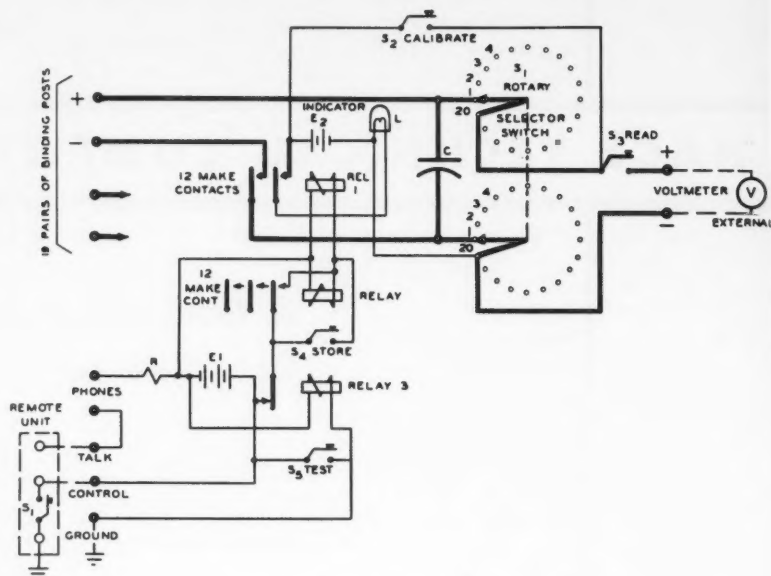


Figure 2—Wiring diagram of concentrator.

TABLE 1—Parts List, Concentrator for Coordinated Corrosion Testing

Diagram Symbol	ITEM	No. Required	Manufacturer	Cat. No.
C	4 mf capacitor wax impregnated paper....	19	W. E. Co.	437A
S ₁	Selector switch, UNIQUE, 20 positions... Etched dial plate.....	1	J-B-T Inst. J-B-T Inst.	MS-20-2 EP-20
S ₂ to S ₆	Switch, nonlocking push button.....	5	Grayhill	23-1
Rel. 1 and 2	Relay, wire spring, 12 make contacts— 2500-ohm, 7.8 milliamp operate.....	2	W. E. Co.	AF83*
Rel. 3	Relay, single pole, double throw.....	1	Potter & Brum.	LB5**
L	Pilot lamp, 2-volt, amber with assembly...	1	Dialight Corp.	555-621
R	500-ohm resistor, $\frac{1}{4}$ watt.....	1		
E ₁	24-volt battery, dry cell.....	1		Note***
E ₂	1½ volt flashlight cell.....	1		
	Binding posts, black.....	22	Superior	5-way
	red.....	20	Superior	5-way
	white.....	2	Superior	5-way
	green.....	4	Superior	5-way
	yellow.....	2	Superior	5-way
	Cabinet, sloping removable front, hinged top $8\frac{1}{2} \times 13 \times 8\frac{1}{2}$	1	Bud	C-1892B
	Chassis, $8\frac{1}{2} \times 12\frac{1}{2} \times 2\frac{1}{2}$	1	Bud	CB-704
	Minibox, $3\frac{1}{4} \times 2\frac{1}{8} \times 1\frac{3}{8}$	1	Bud	CU-2101
	Tekni-Labels.....	1	Tekni-Labels	101
	Chassis, punch, $\frac{1}{2}$ " D.....	1	Greenlee	733

* U144 Type Relay can be used in place of the AF83 when this relay is not available.

** An R27 or R1051 Western Electric Relay, which has a winding of 3500 ohms and requires 4.8 milliamperes to operate, may give more positive operation than the P & B Relay shown in the parts list.

*** 22½-volt battery may be more readily available.

disconnection remains stored in each of the capacitors.

A rotary switch (S1) is provided so that the voltages of each of the capacitors can be read off in sequence at the convenience of the observer. A momentary contact push button (S3) directs the voltage into an external voltmeter when the observer is prepared to read. The use of a million-ohms-per-volt meter lengthens the discharge time of the 4 mf capacitors so that ample time is afforded for a precise reading.

The selection of 4 mf sized capacitors is somewhat arbitrary. Actually it is not mandatory that all nineteen of the capacitors be exactly alike. The voltage assumed by the capacitors is independent of the capacitance within rather

wide limits. Because the resistance of the test leads is relatively low, the 4 mf capacitors will have a short charging time constant (based on $t = CR$) and the stored voltages therefore will follow rapid fluctuations. On the other hand, because of the high resistance of the external voltmeter, the discharge rate (again based on $t = CR$) will be long. This allows ample time for the observer to make a reading. The capacitors are of the wax impregnated paper type having very low leakage and thus will hold a charge for a considerable length of time during the wait for individual readings.

As accessory to the essential circuitry, an indicating lamp has been added which lights only when the ca-

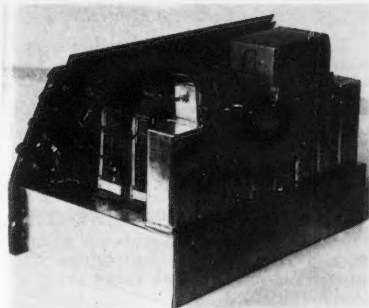


Figure 4—End view of equipment with cabinet removed.



Figure 5—Remote control unit

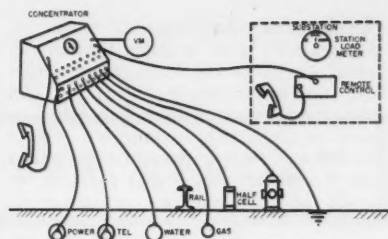


Figure 6—Typical setup of concentrator for coordinated corrosion testing.

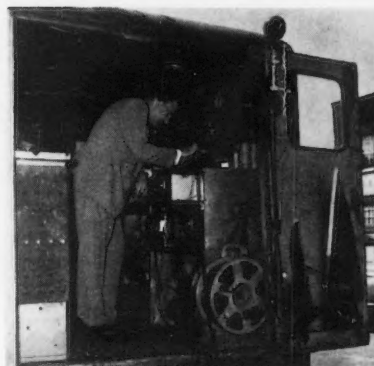


Figure 7—Photograph of a field test setup.

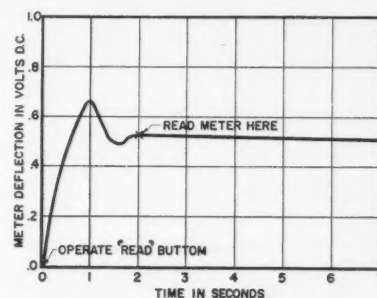


Figure 8—Typical dynamic response of voltmeter.

capacitors are connected to the external test circuits and are in the storing condition. As another added feature, a momentary contact push button has been provided by which a 1.5 volt charge from the 1-cell battery can be put on each capacitor and then "read out" in sequence as a quick check of the circuitry of the test box prior to actual testing.

A printed card mounted on the top lid of the cabinet gives step-by-step instructions for establishing the test set-up and testing procedures.

Figure 3 is a top view of the inside of the test box with the cabinet removed. The parts lend themselves nicely to simple compact construction. The drawer type assembly makes for easy battery replacement and other maintenance.

Figure 4 is an end view of the inside of the test box with the cabinet removed. It gives a side view of the wire-spring relays and indicates the manner of mounting the two batteries.

Remote Control Unit

Figure 5 shows a remote control unit that has been provided for situations which often arise when the person who is in a position to know when the optimum moment for testing occurs, is not located at the point that is convenient for the set-up of the test box and its associated test circuits. The remote unit consists simply of a Minibox carrying a push button which will release the gang switches in the test box at the desired instant of test. The indicator lamp is then extinguished indicating the ready-to-test condition to the meter observer. Provision also has been made for a telephone line between the remote unit and the test box.

Parts List

Table 1 is a combined parts list for the test box and the remote control unit. The original model, as built and shown in Figure 1, used 38 large binding posts for the test leads and 12 smaller binding posts for the auxiliary connections. The small posts were originally selected because they were then available in distinctive colors. The parts list indicates all binding posts to be the large type (5-way) because such posts are more rugged and therefore are more suited to field testing. In addition they also are available in the desired colors. The material cost for the original model of the test box was approximately \$52 exclusive of strapping wire. No labor costs were kept.

Typical Application of the Concentrator

Figure 6 is a sketch of an actual field set-up typical of the several uses to which the test box already has been applied successfully. The specific problem covered in this paper was the readjustment of the grid resistors in each of the drain wires between the various underground utility structures and the negative bus-bar in a DC substation of the Cleveland electric transit system.

The proper amount of stray earth current that should return over each utility via the drainage wires to the substation must be carefully determined on a joint field test basis. Overdrainage and underdrainage both have adverse corrosive reactions on the underground plant involved. Test lines were run by each utility to the known critical points, where they were connected to the lead sheaths of power cables and telephone cables and also to water mains, gas pipes and street car rails. Several utilities required tests at more than one critical point, thus involving a total of 12 test lines in this particular test. The meter used was a Model HS, Sensitive Research Instrument Corporation voltmeter with a zero center scale. When set at the 10-volt scale this meter had an input resistance of 10 million ohms.

After the test circuits were connected to the concentrating test box, the services of only three persons were required to complete the survey. These individuals consisted of a meter reader, a data recorder and a person to operate the remote control unit located at the load meter panel in the electric railway substation. Figure 7 is a photograph of the test set-up which was shown diagrammatically in Figure 6. It is quite a simple matter to provide adequate shelter for the test box, the meter, the single observer, and the data recorder. The telephone set seen worn by the observer is connected with a similar set worn by the data recorder seated in the front of the truck. It also is connected with the engineer operating the remote control box and the meter panel in the electric railway substation. It is to be noted that the simplicity of the test procedure contrasts sharply with the previous hectic arrangement where at least 12 persons and as many meters would have had to be assembled in some kind of shelter and their coordinated action maintained.

Data Taken With Concentrator

Twenty-eight sets of readings, each involving 12 test circuits, were taken in one hour. Tests covered a wide range of substation loads. A large num-

ber of tests were necessary to ascertain that the grid resistor adjustments decided upon were effective at all values of load current. The ease with which the tests could be made with the test box encouraged the testers to take an adequate number of readings. It developed that a series of readings could be stopped and retested very readily without any appreciable waste of time, in the event that the validity of the data was questioned. It was necessary only to press the "Store" button which sets up the condition for storing a new set of readings.

When the field data obtained in these tests were later plotted, they were found to have excellent correlation. All of the points fell on very regular lines and there was an absence of the widespread and unexplainable off-points that were characteristic of data taken on previous surveys conducted without the test box.

In reading the external voltmeter, it is necessary to take into account the ballistics of the meter movement. Figure 8 is typical of the response curve that results when a million-ohms-per-

volt meter is used connected to the 10-volt scale. It is to be noted that on the initial discharge of the capacitor under test, the meter needle overruns and underruns momentarily and reaches stability in about two seconds. The stable condition indicates the correct voltage which remains substantially constant for ample time to assure an accurate reading.

Instrument shunts with 50 millivolt drop are provided in the utility drainage panels in the electric railway substation. They are used for measuring

return currents. The million-ohms-per-volt meter was not suitable for measuring voltages in this millivolt range because of the low input resistance associated with the low voltage meter scales. The low input resistance caused the storage capacitors to discharge at such a rapid rate that voltage readings were impracticable. This difficulty will be overcome in subsequent tests by the elimination of the sensitive voltmeter and the substitution of a battery operated vacuum tube voltmeter having a 100 megohm input.

Conclusion

The occasions for which large scale coordinated field tests are required are happily infrequent. However, a few elaborate or even simple applications of the concentrator should result in sufficient savings in manpower and meters to justify the very nominal cost. In the case of the Cleveland survey, which will ultimately involve 17 electric railway substations and require perhaps as much as two years to complete on an intermittent basis, the advantages seem obvious.

NACE TECHNICAL COMMITTEE REPORT

Methods for Measuring Leakage Conductance of Coating On Buried or Submerged Pipe Lines

*A Report of Technical Unit Committee T-2D on Standardization
Of Procedures for Measuring Pipe Coating Leakage Conductance⁽¹⁾*

Object

THE OBJECTIVE is to present some of the methods of measurement of the leakage conductance of sections of buried or submerged pipe lines. The ultimate aim is the establishment of a set of uniformly applicable methods for the measurement of this quantity.

Foreword

Two difficulties lie in the way of the establishment of any kind of "standard" method for the measurement of this quantity:

(1) as it is found on existing pipe lines, the quantity itself varies through an enormous range, far greater than that of most quantities commonly measured; and

(2) in contrast with the majority of such determinations which have been standardized, the conditions are not subject to laboratory control; the problem here is the measurement of the leakage conductance *in situ*, with all of the accidental variables present.

There is a demand for a method so explicit that a competent technician could, by following a set of directions, carry out the field work necessary for the determination of conductance. Unfortunately, the complexity inherent in the subject matter—"buried or submerged pipe lines"—is such that no such simple set of directions can be devised. There is also a demand for a method, or set of methods, which are scientifically and technically complete and precise. Again, the inherent complexity of the subject is such that no such complete set of methods has been devised. It is to be hoped that the second demand can ultimately be fulfilled; the first seems to be beyond hope of realization at the present state of the art.

⁽¹⁾ Marshall E. Parker, Cormit Engineering Co., Houston, chairman.

Definitions

The **leakage conductance** (k) of a pipe line is the current per unit length which passes when unit potential exists between the pipe and remote earth. This quantity (k) is affected by:

1. The physical characteristics and condition of the coating,
2. The conductivity of the surrounding soil, and
3. The contact resistance between the pipe and the soil.

(There is an implicit assumption here that the ratio between the current and the potential is constant; i.e., that the value of conductance obtained is independent of the impressed potential. Although this assumption is probably not valid, it is believed that the discrepancies will be small when the values used are within the range used in cathodic protection).

Remote earth refers to an electrode location sufficiently far from the pipe line that further separation does not appreciably alter the readings obtained.

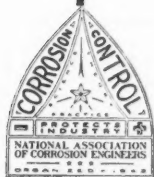
(The "remote earth" concept is essential to this measurement because all of the theory concerning the distribution of current and potential along a line is based on reference to remote earth. When the coating is "good" an electrode position directly over the line is electrically remote, and should be used).

Units

The basic unit for leakage conductance is **conductance per unit length**. The most commonly used unit is **micromhos per foot**.

For comparisons on an area basis, this may be converted to **micromhos per square foot** by dividing by the circumference of the pipe expressed in feet.

(Caution should be used in attempting to compare coatings on lines of different diameter since equivalent coatings do not



necessarily behave similarly when diameters are different because of current density effects. The commonly encountered unit "ohms per square foot" is logically unsound, since total resistance is obviously not proportional to area; an admissible unit is ohm-square feet, which is merely the reciprocal of mhos per square foot).

Basic Method

The basic method of determining leakage conductance is:

1. An interrupted current is drained from a selected point on the line, and discharged to earth at a sufficient distance that no part of the line section under test lies within the detectable anode potential gradient.

(The needed separation of the anode from the test section may be obtained either by distance along the line from the drain point to the nearest point of the section under test, or by lateral separation of the anode from the line. Separation in excess of the minimum required is not undesirable).

2. The change in the total current flow to the section under test is determined, as the test current is interrupted. This quantity is designated as ΔI .

3. The average change of potential of the section with respect to remote earth is determined. This quantity is designated as ΔE .

(The determination of the true average value of ΔE is the most difficult problem involved in the measurement of leakage conductance. As will be stated later, the arithmetic mean between the two end values is a sufficiently accurate approximation under certain conditions but there are circumstances under which this simple mean is grossly erroneous).

4. The average leakage conductance of the section will then be given by the expression

$$k = \frac{\Delta I}{\Delta E \cdot L}$$

where L is the length of the section.

(If the leakage conductance of the section is truly uniform, then the same value of k will be obtained by any measurement performed, within the limits of experimental error. If, however, the conductance is not uniform, then measurements made with different drain points will yield different values, as greater weight will be given to the portion of the line nearest the drain point).

5. A sufficient number of readings is to be taken to insure acceptable precision.

(The value obtained for leakage conductance, by the most careful methods, is not reproducible with great accuracy. It should be remembered that this quantity varies through an enormous range and that two coatings which differ by, say, a ratio of 2:1 are actually quite comparable. Measurements repeated under identical conditions—i.e., using the same drain and test points and with only small lapses of time, should agree more closely—within 10 or 20 percent).

Alternate Methods

The quantity (k) may also be determined by means of the established mathematical relationships between the electrical characteristics of a line, as

expressed in the theory of attenuation; any suitable set of measurements may be taken, as appropriate to the particular line section under study.

(The attenuation method is a very powerful tool for the investigation of the electrical behavior of pipe lines; the method is so general, however, that a detailed statement of all of the possible applications would be very extended; in the hands of a skilled mathematician, this method will often afford reliable results with far less field work than could possibly be specified in any standardized procedure).

Classification of Lines

Different techniques of measurement are required on long and short pipe line sections; these are defined as follows:

A long line is one whose length is such that, when a suitable test current is drained from it, the potential change (ΔE_L) at the end of the line is too small to be useful.

A short line is an electrically isolated section of line of such length that, when a suitable current is drained from it, the potential change (ΔE_L) at the most distant end is large enough to be measured with acceptable accuracy.

(Note that, in the case of a long line, it is immaterial whether the far end is insulated or not; it may even be connected to a structure of quite different electrical characteristics, such as a bare line or a tank farm; a short line, however, must be an isolated section for the method described to be applicable. The distinction is made because of the difference in the method of measuring current.

It is obvious that there will be lines which can be considered as either long or short; i.e., either method may be used. In such cases the judgement of the engineer in charge must determine the procedure).

Short Line Test Methods

1. The pipe of which the section is composed should be of uniform nominal size and weight. If this is not the case, the line should, if possible, be treated as a long line, and measured in sections. If this is impossible, then the distribution of the different weights and sizes should be reported with the results.

(Composite short lines can be handled by use of attenuation methods, but not by the simplified procedures here presented).

2. Location of Anode. A minimum distance of 400 feet should separate the anode from the nearest point of the test section, unless the quantity $D = I\rho/50$ is less than 400, in which case the distance D (feet) can be used. In the expression given for D , I = the drain current in amperes and ρ = the soil resistivity in ohm-centimeters.

(These distances are valid for tests run with the electrode directly over the line, for an electrode so placed it is in nearly the same part of the anode field as is the pipe; when a remote electrode is used, the anode separation must be much greater.

Frequently a convenient arrangement is the drainage of current across an insulated joint at the end of the line; when this is done, the effective separation of the anode is quite large, and no difficulties are to be anticipated from anode gradients).

3. Measurement of current. The value of ΔI is obtained by the readings of an ammeter inserted in the drainage circuit. A minimum of two values of ΔI should be used, with a ratio of approximately 2:1, and the corresponding values of k determined.

(Care must be taken that the section is truly isolated; insulated joints must be carefully checked).

4. Determination of average potential change. Two cases are recognized. If the ratio $\Delta E_o/\Delta E_L$, where ΔE_o is the potential change at the drain point and ΔE_L is that at the far end, is not greater than 1.6, then the arithmetic mean between the two can be used for the average ΔE . If the ratio $\Delta E_o/\Delta E_L$ is greater than 1.6, then the corrected value of the average is obtained by multiplying ΔE_L by the factor from Table 1.

(In general, values beyond 3.0 will not be dealt with by short line methods.

The correction factor can be applied to cases where the ratio is less than 1.6, but the error without the factor will in such cases be less than 10 percent.

(Derivation of this factor is as follows: The true value of the mean ΔE for finite line is given by

$$\Delta E_M = \Delta E_L \sinh \alpha \frac{L}{\alpha L}$$

We have also that

$$\frac{\Delta E_o}{\Delta E_L} = \cosh \alpha L$$

The table gives

$$\sinh \alpha \frac{L}{\alpha L}$$

as a function of $\cosh \alpha L$).

Long Line Test Methods

1. Every subsection which is tested should be of pipe of uniform nominal size and weight. If a section of pipe having characteristics which differ from adjacent sections is too short to be treated as a subsection, then its existence and location should be reported in the results.

(Composite lines with short sections can usually be handled by attenuation methods, but not by the simplified procedures here presented).

2. Location of anode. The same limitations apply as in the case of short lines.

(If the initial value of line current (ΔI_o) is to be determined by line current measurement, rather than by use of an ammeter, the separation needed can be obtained by distance along the line; distances greater than the prescribed 400 feet are advantageous).

3. Measurement of current. For each section of a long line studied, two values of current must be measured,

TABLE 1

$\Delta E_o/\Delta E_L$	Factor	$\Delta E_o/\Delta E_L$	Factor	$\Delta E_o/\Delta E_L$	Factor
1.0	1.000	1.7	1.224	2.4	1.433
1.1	1.032	1.8	1.254	2.5	1.461
1.2	1.066	1.9	1.286	2.6	1.492
1.3	1.099	2.0	1.315	2.7	1.520
1.4	1.130	2.1	1.345	2.8	1.548
1.5	1.163	2.2	1.375	2.9	1.576
1.6	1.193	2.3	1.404	3.0	1.604

one at each end of the section. The initial value, if one end of the line terminates in an insulated joint, may be measured with an ammeter. This value is designated as ΔI_0 . The terminal value must be measured by the IR drop in a measured length of the line. This value is designated as ΔI_L . A span of sufficient length must be used to insure an accurate determination of the current.

A length, in feet, numerically equal to twice the pipe weight, in pounds per foot, is suggested as the practical minimum span; this will give a resistance of approximately 0.0005 ohm).

This IR drop should be measured with a millivoltmeter, making the necessary corrections for lead wire resistance, or with a potentiometer. Lead wires attached to the pipe should be used; contact bars are not recommended.

The practical maximum distance from the initial point is determined by the distance at which ΔE can be determined with useable precision; the practical minimum distance is that at which the difference between ΔI_0 and ΔI_L can be measured with useable precision.

If the resistance of the pipe is not known with sufficient assurance, it may be determined by the following method:

A set of six leads is installed on the pipe, as shown in the diagram. The length X of the calibrated section should conform to the requirements given above for a current measuring span. The length Y of the "end-loss" section should be comparable, and may be identical. The distances identified as "3d" should each be at least three times the outside diameter of the pipe, and may be greater.

A measured current of I amperes is passed through the two leads "i—i." The change in potential E_x millivolts across the leads "e—e" corresponding

to the interruption of this current is measured, as is the change in potential E_y millivolts across the leads "e'—e'." The conductance of the calibrated section "e—e" is then given by

$$K = \frac{IY}{E_x Y + E_y X}, \text{ in amperes per millivolt.}$$

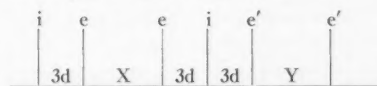
If $Y = X$, then

$$K = \frac{I}{E_x + E_y}$$

If $E_y = 0$, i.e., if there is no end loss, then

$$K = \frac{I}{E_x}$$

The total current ΔI , flowing to the test section is given by $\Delta I_0 - \Delta I_L$.



4. Determination of average potential change. ΔE_0 and ΔE_L are to be read at the same points as the corresponding values of ΔI . If the ratio $\Delta E_0/\Delta E_L$ is not greater than 1.6, then the arithmetic mean of the two can be taken as the average potential change. If the ratio exceeds 1.6, one or more intermediate points should be selected for potential measurements only, such that the ratio between two successive values does not exceed 1.6. Then the average potential change of each subsection is the arithmetic mean of the two end values, and the average for the entire section is the arithmetic average, weighted by lengths, of the subsection averages.

(If recourse is had to attenuation theory,

the value of k can be obtained from the readings described without computing the subsection averages directly. The application of these methods must be left to the judgement of a competent engineer).

Reporting of Results

In addition to the basic data, the measured leakage conductance of the pipe line section, the following should be reported:

1. A description of the line of which the section is a part, including its length, method of termination, diameter, pipe weight, type of joints and location.

2. A description of the section tested, including its length, location, method of termination and any particulars in which it differs from the line as a whole.

3. A description of the coating on the tested section, including its materials, age at time of test, specifications under which it was applied and other relevant data, so far as they are available.

4. The presence or absence of parallel and crossing lines and other structures which might influence the distribution of current and potential, including cased crossings, laterals, valves, drips and similar structures.

5. The cathodic protection history of the line, so far as it is known.

6. The corrosion history of the line, so far as it is known.

7. The soil resistivity of the terrain in which the line lies; all such data as may be available should be reported, including the number of measurements made, the spacing of such measurements, instrumentation and method used. Leakage conductance with no data on soil resistivity is virtually meaningless.

8. Instrumentation used in the tests and any information concerning the conduct of the test which might prove useful in its interpretation.

9. The field data taken (may be in summarized form) and the calculations by which the results were obtained.

Influence of Crystal Face On the Surface Properties of Metals

By A. T. GWATHMEY*

Introduction

STUDIES HAVE been carried out at the University of Virginia for some years on the influence of crystal face on the surface properties of metals. The general method of study¹ consists of preparing single crystals in the form of spheres of about five-eighths inch in diameter and of studying the chemical activities of the different faces on these specimens. In some cases specimens in the form of circular disks exposing one crystal face are used. The crystals are electrolytically polished in order to remove strained material and to obtain surfaces which are as nearly plane as possible. They are annealed in hydrogen at about 500 C before being exposed to the reacting chemicals.

Surface Processes

A number of surface processes have been studied in different degrees of intensity on crystals of about a dozen metals. Most of the studies have been carried out with copper, nickel and iron. The following processes have been studied: oxidation, corrosion, catalysis, electrochemical properties (including electroplating), wetting, bonding, and friction and wear.

Within the field of corrosion, the rates of oxidation of the different faces of a copper crystal recently have been determined over the temperature range of 70-180 C with the aid of elliptically polarized light,² and it was found that the thickness of the oxide film on one face was 2 to 20 times that on another, depending on the conditions of the experiment. The structure of the oxide film with respect to that of the underlying metal also was studied with the aid of X-ray³ and electron diffraction, and it was found that the orientation and the texture of the oxide varied greatly with face.

More recently studies have been carried out by Harris and Ball of the Union Carbide Nuclear Company at Oak Ridge, in association with the author, on the texture of the oxide film as determined with the aid of the electron microscope at a magnification of approximately 50,000. It was shown that the oxide within any one face consists of a base film of oxide which is interspersed with small nuclei of oxide and larger particles of oxide in the shape of

definite polyhedra. At the present time studies are being carried out to determine what influence impurities and imperfections in the lattice may have on the formation of the nuclei and polyhedra. Efforts at the same time also are being made to prepare crystals of very pure metal with a reduced number of imperfections. It is hoped in the future to obtain crystals with a controlled number of imperfections.

Effect of pH on Etching

Since very little is known about the effect of crystal face on corrosion of metals by liquids, the etching characteristics and potentials of different faces of copper single crystals are being studied. Using the system $\text{CuSO}_4\text{-H}_2\text{SO}_4$ it was found that the pH of the solution affected the degree of etching on the various crystal faces. At a pH of 4 an oxide pattern was observed on a spherical single crystal. In the pH range from 3 to 0, etch patterns of varying complexity were observed. The (111) and (100) faces were not etched under these conditions, but the area immediately surrounding the (111) face was heavily etched. The (110) face was either etched or not etched, depending on the pH.

Studies now in progress on corrosion by liquids include the measurement of electrode potentials of the faces relative to a standard electrode, of the electrochemical potential differences between any two faces, and of the effect of dissolved oxygen on both etching characteristics and potentials. The potential measurements are concerned not only with the equilibrium values, but also with the initial non-equilibrium changes in potential. In general, crystal face has been found to play a significant role in corrosion.

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Compatibility of Aluminum With Alkaline Building Products*

By C. J. WALTON, F. L. McGEARY and E. T. ENGLEHART

Introduction

ALUMINUM alloys, because of their versatile properties and characteristics, including good resistance to corrosion, are being used in increasing tonnages in architectural, structural and engineering applications. Aluminum formerly used for specialty applications has become a major material of construction and as such must coexist with a wide variety of other building materials, both metallic and non-metallic.

When dissimilar metals are involved, the hazard of galvanic corrosion must be considered. This consideration has been weighed sufficiently so that performance of aluminum alloys in direct contact with dissimilar alloys can be anticipated at least to an extent permitting selection of the most compatible combinations.^{1,2,3}

Non-metallic building materials, when wet, may cause corrosion of metals by chemical action, by differential aeration effects and by supporting galvanic attack between dissimilar metals. It is important, therefore, to acquire factual data on the corrosive effects of contact of metals with non-metallic building materials under moist or wet conditions. This has been a subject of research at the Alcoa Research Laboratories for many years and many of the findings have been utilized in the building and construction field.

Many non-metallic building materials are alkaline because they contain Portland cement, lime, magnesium compounds or asbestos. These materials are of particular interest because of the large volumes employed and because many persons are not familiar with the ability of aluminum to resist corrosion caused by such products. It is the purpose of this paper to summarize the pertinent data on the behavior of aluminum alloys in contact with alkaline building materials.

Chemistry

Resistance to corrosion of aluminum alloys is attributed to a thin, invisible oxide coating that develops naturally over their surfaces. It has been indicated by McKee and Brown⁴ that in exposures to neutral or nearly neutral solutions, pH 4.5 to 8.5, the film is fortified by the formation of additional hydrated alumina to increase its resistance to the new environment.

Alkaline solutions (and acid solutions), however,

Abstract

A series of tests is reported on the reaction of aluminum alloys to alkaline building materials under a variety of conditions. After a discussion of the chemistry of reactions between aluminum and alkaline building products, results of a series of laboratory tests are given.

Evaluations of effects by visual inspection, galvanic corrosion current measurement, weight loss and microscopic examination were made. These included subjecting alloy 3003-H14 to a series of exposures to asbestos cement products, insulation materials, alkaline flooring materials, mortar and concrete cured dry and wet, and assessing the effects of galvanic couples to steel in varying ratios up to 1:12, and at spacings from 4 inches to 3/8-inch; effects of chlorides, curing conditions, and others.

Mechanism of corrosion in mortar and concrete is examined and a study is made of polarization characteristics of an aluminum-to-steel couple in mortar. Stray currents are cited to explain infrequent cases of severe corrosive attack of aluminum in concrete.

Tests reveal, and related service experiences confirm, that aluminum corrodes only superficially when exposed to alkaline building products and that this corrosion is self-limiting in nature. Protective measures may be needed in cases involving dissimilar metals and differential aeration effects in the presence of relatively high chlorides.

6.6.5

tend to dissolve the existing oxide coating. These solutions will attack aluminum, but in doing so they develop other types of films. The films that form in sodium hydroxide are highly soluble and high rates of attack ensue. In contrast, the films that form in calcium hydroxide, magnesium hydroxide or ammonium hydroxide have limited solubility and form a highly resistant barrier against further attack. Thus, building products or leaches of such products whose alkalinity is derived from calcium or magnesium hydroxides may cause over-all surface attack of bare aluminum, but the process develops protective films that resist further corrosion. Such alkaline materials cause only superficial or mild surface attack, with most of the attack occurring during the initial stages of exposure. During the curing or aging process, free alkali is converted to carbonates that have even less action on aluminum.

Drainage from freshly applied materials, such as concrete, plaster, mortar, stucco and asbestos cement products, is highly alkaline. Such drainage or leachings are sufficiently alkaline to attack unprotected aluminum. Although this attack usually is only superficial, it is sufficient to cause discoloration.⁵ Such attack is most likely to occur during the period of construction, or shortly thereafter. Rains soon leach away readily available alkali from the surface, so that subsequent leachings contain too little alkali to

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E. T. ENGLEHART—Has worked on fundamental and practical problems of corrosion and corrosion-prevention of aluminum alloys as a member of the Chemical Metallurgy Division, Alcoa Research Laboratories, Aluminum Company of America. He holds a BS in chemistry from Pennsylvania State University, 1943, when he joined Alcoa. Author of several papers on the corrosion of aluminum alloys, he is a member of NACE.



attack aluminum. Staining of aluminum can be effectively prevented by application of a clear, methacrylate resin coating. This finish has been used on windows, doors, trim and other architectural parts to avoid discoloration during construction and to facilitate removal of mortar and the like, after construction.

Laboratory Test Procedures

A variety of tests was used to determine the compatibility of aluminum alloys with alkaline building materials. Attempts were made to simulate service conditions, relative to size of material and method of assembly. Preformed, non-metallic materials generally were sandwiched between two pieces of metal. These pieces were either both aluminum or aluminum and a dissimilar metal, either electrically coupled to each other or uncoupled. The latter condition permitted study of galvanic corrosion. Special treatments, such as the introduction of protective coatings or corrosion inhibitors, were incorporated in duplicate test assemblies. These sandwich-type assemblies generally were exposed to a warm, moist environment, usually 100 percent relative humidity at 125 F. The nominal period of exposure was six months.

For monolithic type building materials, such as

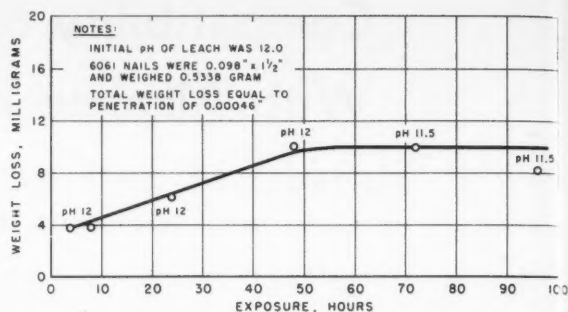


Figure 1—Effect of exposure of 6061 aluminum nails to a water leach of 1.891 grams (1/2-inch diameter circle) of asbestos cement siding. This curve indicates the self-limiting corrosion rate of aluminum alloy products exposed to water leaches of asbestos cement siding. While alkalinity remained relatively unchanged, weight loss of aluminum alloy nails did not increase after the first 50 hours. Corrosion amounted to only 0.00046-inch penetration in 100 hours.

TABLE 1—Alkaline Building Products

Evaluated for Compatibility with Aluminum Alloys
at Alcoa Research Laboratories

Asbestos Cement Refractory	Dry-Wall Board—Cement Type
Insulation	Dry-Wall Board—Gypsum Type
Asbestos Cement Shingles and Roofing	Grouting
Asbestos Insulation Paper	Gypsum Plaster
Calcium Silicate Type Refractory Insulation	Iron-Bearing Cement
Cast Stone	Latex Cement
Castable Refractory Cements	Lime Plaster
Concrete	Limestone
Concrete—Bubble Slag Aggregate	85% Magnesia Refractory
Concrete—Pre-Cast	Insulation
Concrete—Air Entrained	Magnesium Oxide Cement
Concrete—Light Weight	Marble
Crushed Slag	Mortar
	Plaster of Paris
	Soft Glass
	Stucco
	Terrazzo Flooring

Listed materials have been found to perform satisfactorily with aluminum alloys under a variety of test conditions. These materials caused no more than mild etching of aluminum alloys, but certain ones were found to support galvanic corrosion of aluminum alloys when electrically coupled to dissimilar metals. In these cases, protective measures were required for optimum performance.

plaster, cements or concrete, aluminum panels were either embedded in the fresh material or the non-metallic was cast upon the aluminum alloy specimens. These casts were then exposed to a variety of moist conditions.

Effects of these exposures on the metals (and on the non-metallics) were evaluated by visual inspection, measurement of galvanic corrosion currents, gravimetric and microscopic determination of the extent of attack. Limited tests were made to determine the nature and composition of the products of corrosion.

The majority of the tests made in the laboratory used aluminum alloy 3003-H14. This alloy, containing nominally 1.25 percent manganese, has been used widely in the architectural field and its performance is representative of that of a large number of aluminum alloys. The steel employed in the laboratory tests was a bright-finished mild steel containing 0.04 percent carbon.

In the tests described later, the term "mortar" refers to a 1:2, Portland cement: sand, mixture. Where "concrete" is specified, three parts of shot gravel were also included.

Test Results and Service Experience

Tests have been conducted at the Alcoa Research

Laboratories on many alkaline building products in combination with aluminum alloys. A list of the materials tested is included in Table 1. Although it is not practical to discuss all in detail, specific information is given on several of the more important types of alkaline building products.

Asbestos Cement Products

Many asbestos cement products are being employed successfully in conjunction with aluminum alloys. These include asbestos cement roofing, insulation and especially shingles. In the case of the asbestos cement shingles, aluminum alloy nails are being used as a corrosion resistant, non-staining fastener. In addition to this, aluminum alloy flashing and trim are being employed extensively with these shingles.

Asbestos cement shingles and other products are highly alkaline in nature, having a pH in the range of 11 to 12. Laboratory tests have shown, however, that aluminum alloys have a high resistance to corrosion even to concentrated leaches of these products. For example, portions of asbestos cement shingles were thoroughly ground and leached with water producing a solution with a pH of about 12. Aluminum alloy 6061 nails were immersed in this concentrated leach for 100 hours. Nails were removed at intervals and evaluated by weight loss. As shown by Figure 1, the rate of attack decreased markedly with time of exposure, although the alkalinity (pH) of the solution remained at a high level. In addition, atmospheric weathering tests were conducted to determine the compatibility of aluminum with these products. Examination after exposure of four years to the seacoast atmosphere at Point Judith, Rhode Island and eight years' exposure to the industrial atmosphere at New Kensington, Pennsylvania, disclosed that nails driven through asbestos cement shingles were in excellent condition, with only superficial attack in evidence. Equally good results are being obtained in service.

The good performance of aluminum alloy nails with asbestos cement products can be attributed to two factors. The first is the physical nature of these products. Since the surface is dense or glazed, it is difficult for appreciable amounts of alkaline materials to leach from them under ordinary service conditions. Secondly, films formed on aluminum alloys as a result of contact with such alkaline products protect the aluminum from further corrosion of any significance.

Insulation Materials

In many applications, aluminum alloys are employed with insulation materials of an alkaline nature. Included are boiler coverings, pipe coverings, wall panels and other industrial applications requiring insulation against relatively high temperatures. These insulations generally use magnesia or calcium silicate as the primary component. They also are used in combination with other fillers, such as asbestos and diatomaceous earths to form a wide variety of products.

In general, these insulation materials were not corrosive to aluminum alloys. Under moist conditions, the magnesia and calcium silicate types caused only slight etching of contacting aluminum alloys. However, when these insulations were sandwiched between electrically coupled aluminum and steel, galvanic corrosion of the aluminum developed under moist conditions. In the light of this, applications where aluminum is being used to sheathe steel equipment insulated with these products should be carefully considered. If insulation becomes wet, some corrosion of the aluminum sheathing might occur, not directly from the insulation but from galvanic corrosion if the steel is coupled electrically to the sheathing.

There are related applications where castable refractory types of cement are used in contact with aluminum. One application of growing interest is the use of aluminum to sheathe power plant boilers, especially those exposed to the weather. The thermal insulation may include a castable refractory and the sheathing may be applied while insulation is wet, thereby introducing the probability of galvanic attack between aluminum sheathing and the inner boiler steel. Laboratory tests showed that this corrosion hazard can be eliminated substantially by adding a corrosion inhibitor to the castable refractory. The addition of 1 percent sodium chromate, by weight, to the dry mix of the refractory substantially inhibited all corrosion. This was used successfully in one large power plant where the boiler was sheathed with aluminum.

Glass fiber products are used for insulation in building applications. Those made from soft glass can be particularly corrosive to aluminum under wet conditions as a result of a strong alkali, probably sodium hydroxide, that leaches from soft glass fibers. However, boro-silicate glass is essentially neutral and is preferred to soft glass for use with aluminum.

Alkaline Flooring Materials

Aluminum alloys are employed as divider strips, decorative moldings and sub-floors in contact with various types of alkaline flooring products. In general, the inherent resistance of aluminum alloys to corrosion by these materials is excellent, despite the fact that the pH of these products ranges from 9 to 10. Because some of these flooring materials are capable of supporting galvanic corrosion between aluminum and dissimilar metals they require special consideration.

One of the major types of flooring materials used in conjunction with aluminum alloys is magnesium oxychloride cement. This cement is prepared from magnesium oxide and magnesium chloride. It is alkaline in nature, water leaches having a pH of about 9.5. Laboratory tests have shown that aluminum alloys in contact with it undergo only superficial etching during the initial curing period of the cement.

This product, however, because of its high chloride content will stimulate galvanic attack between dissimilar metals under moist conditions. Laboratory investigation disclosed that the performance of aluminum both by itself and when coupled to dissimilar

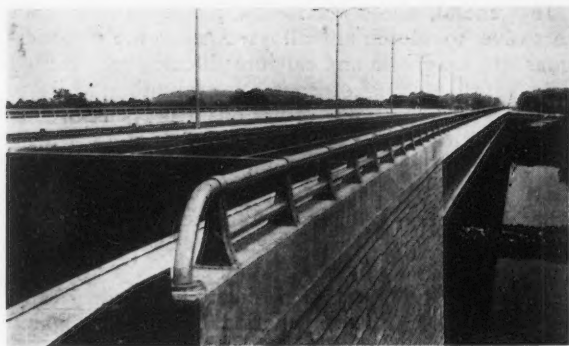


Figure 2—View of East Capitol Street Bridge, Washington, D. C., showing aluminum parapet type highway railings and light standards used in contact with reinforced concrete. In installations such as this, surfaces contacting concrete generally are coated with an alkali resistant paint or mastic. Elsewhere, the aluminum parts are unprotected and do not require maintenance.

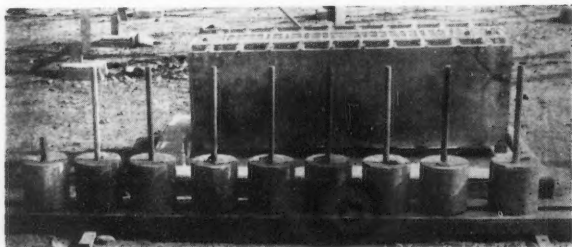


Figure 3—A group of rods embedded in concrete and exposed for eight years to the seacoast atmosphere at Point Judith, Rhode Island. Similar specimens were exposed to the industrial atmosphere at New Kensington, Pa., and to indoor conditions. Examination of the rods, upon removal, revealed an average depth of attack of from 1.7 to 2.4 mils, with maximum depth not exceeding 5 mils. These data indicate, upon comparison with data from much shorter tests, that corrosion of aluminum in concrete is self-limiting.

In the background are shown the bases of aluminum alloy exposure racks anchored to aluminum structurals projecting from concrete footings. Proximity to the ocean (300 feet) had little effect on aluminum alloys partially set in concrete.

metals is markedly enhanced through inhibition of the cement by the addition of 1½ percent potassium dichromate (by weight of dry mix). Benefits of this inhibition have been substantiated by considerable service experience, and it is now a commonly accepted practice⁶ where aluminum alloys are involved. The use of heavy-bodied bituminous or asphaltic type protective coatings also was found to be helpful in retarding corrosion of this nature.

Mortar and Concrete

The weight of concrete used in the United States in a recent year exceeded by far the combined weight of total U. S. production of all metals plus all the brick, tile and lumber.⁷ Considering the extensive uses for concrete, it is not surprising that aluminum and others metals of construction are employed in a variety of combinations with it. It is important, therefore, to establish the effect of various factors that may influence the performance of aluminum in association with concrete. Some of these factors, including (1) direct contact with concrete, (2) volume

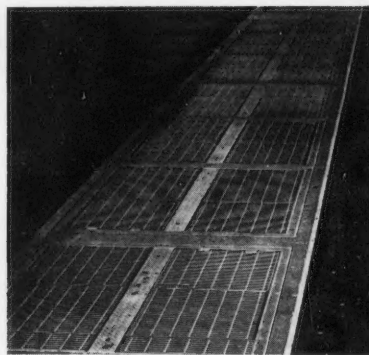


Figure 4—View of aluminum alloy sidewalk vault frames used by a large power company for more than twenty years. These unpainted frames are embedded in concrete and have given trouble free service.



Figure 5—This shows a 43 aluminum alloy cast ramp anchor approximately 4-inches square which had been embedded in outdoor concrete curb for 27 years.

The top and front (T slot) were freely exposed to the weather; the right side (shown), as well as the other three sides, had been set in concrete and remained in excellent condition.

of concrete, (3) moisture retention and (4) galvanic effects, have been evaluated and are discussed in this paper.

Concrete usually consists of a mixture of Type I Portland cement, sand and aggregate. The concrete generally employed in the laboratory tests consisted of a 1:2:3 mix of Type I Portland cement, washed river sand and shot gravel. Tests by Wright, Godard and Jenks⁸ showed that the brand of cement used is not important, thus indicating that any corrosion tests using but one brand of cement may be considered as being typical of the action of commercial cements. Following are some of the data obtained in a series of tests made over the past several years.

Direct Contact With Pre-Cast Products

Aluminum alloys are extensively used for highway railings, (Figure 2) light standards, windows, building sheathing, copings, flashing and many other applications which involve contact with pre-cast mortar or concrete. Considering the permanent nature of such applications, it is common practice to employ protective coatings on the aluminum surfaces to

offset any unusual conditions that may arise as a result of contact between these two materials of construction. A large volume of service experience indicates that aluminum alloys have performed very well under diverse conditions.

Aluminum Embedded in Mortar or Concrete

In many applications, aluminum alloys embedded in fresh mortar or concrete have been used successfully. Some attack does occur during the first few hours of exposure, while the concrete is still fluid, but this generally is of a minor nature. Further attack is retarded greatly because of the formation of highly protective films. This self-limiting type of corrosion has been determined by laboratory tests (Figure 3) and substantiated by service experience (Figures 4, 5, 6). The measured depth of attack occurring during the setting period of concrete is generally less than one mil; depth of attack after six months or after eight or 27 years was no greater than five mils (Table 2).

Effect Of Concrete Volume

A test was made to determine the effect of increasing concrete volume on the corrosion rate of embedded aluminum alloy panels. In this test, aluminum alloy specimens (1 x 6 inches) were embedded in blocks of concrete varying in volume from 56 cu. in. to 384 cu. in. After curing at room conditions for two months, the samples were removed and the amount of corrosion was calculated from weight loss data. As shown in Figure 7, the corrosion increased to some extent as the volume of the concrete was increased. However, the corrosion of the aluminum alloys was of little significance even in the larger volumes of concrete. Thus, it would appear that the volume of concrete in which aluminum alloys are embedded is of only minor importance in the performance of the aluminum alloys under such conditions.

Effect Of Moisture Retention

Another factor that might affect the performance of aluminum embedded in concrete is the continued presence of moisture. In other words, concrete cured under continuously wet conditions might have a different effect on embedded aluminum than concrete cured under dry conditions. To investigate this possibility, three blocks of concrete were poured with embedded aluminum alloy panels. One block was poured in a perforated plastic form and immediately immersed in water for the duration of the test (3 months). Two duplicate blocks were poured and permitted to set under dry conditions. One of these was allowed to cure at room conditions for six months, while the other was immersed in water 24 hours after pouring and cured under these conditions for six months. The sample immediately immersed in water was cured under these conditions for three months. At the end of these curing periods, the test samples were removed and the effects of exposure evaluated by weight loss determinations and depth of attack measurements. As illustrated in Table 3, the aluminum alloy was little affected under all conditions, indicating that the availability of external

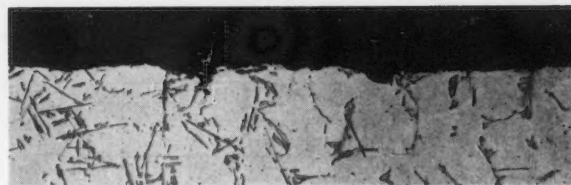


Figure 6—Photomicrograph of a section of the 43 alloy cast ramp anchor shown in Figure 5. The fact that the attack was shallow (average depth of attack, 1.4 mils) can be observed readily. 100 x Keller's Etch.

TABLE 2—Results of Metallographic Examination for Depth of Corrosion on Aluminum Alloy Specimens Embedded in Concrete¹

Time in Concrete	Aluminum Alloy	Average ² Depth of Attack—Mils	Maximum Depth of Attack—Mils
1 hour.....	3003	0 -0.1	0.4
6 hours.....	3003	0.1	0.4
24 hours.....	3003	0.1	0.4
9 days.....	3003	0.4	0.7
28 days.....	3003	0.6-0.9 ³	1.3-1.5 ³
60 days.....	3003	0.1-0.4 ³	0.5-1.1 ³
90 days.....	3003	2.9 ³	4.3 ³
6 months.....	3003	0.2-1.8 ³	0.6-4.3 ³
8 years Indoors.....	{ 6053 2017	1.7	5.0
8 years Industrial Atmosphere ⁴		1.9	3.8
8 years Seacoast Atmosphere ⁴		2.4	4.4
27 years cast alloy—Industrial Atmosphere.....	43	1.4	4.1
27 years wrought alloy—Industrial Atmosphere.....	6051	1.4	2.6

Notes:

¹ Measurements on specimens embedded either in mortar or concrete are included in this table. Laboratory tests have shown that the addition of aggregate to mortar has no significant effect on performance of embedded aluminum alloys.

² It should be appreciated that this value is the mean of individual sites of attack and does not integrate the area over which no attack or insignificant attack had occurred.

³ These specimens were embedded in concrete which had been kept continuously wet during the exposure period.

⁴ These specimens were embedded in concrete which was freely exposed to atmospheric conditions. In all other cases, the concrete was allowed to cure under room conditions.

moisture had no more than a minor effect on the performance of aluminum embedded in concrete.

Effect of Galvanic Couples In Concrete

Previous results showed that aluminum simply embedded in concrete suffered mild over-all surface corrosion of little consequence. In various structural applications, however, aluminum may be directly or indirectly coupled to embedded reinforcing or structural members of steel. Laboratory tests showed that aluminum alloys are anodic to mild steel in concrete, but little information was available about the effects of various factors, such as relative area of steel and curing conditions, on the galvanic corrosion process. Several tests were made, therefore, to provide information of this nature.

Effect of Cathode Area. To evaluate the effect of variations in size of cathode area, 1 x 6-inch panels of 3003 aluminum alloy were embedded in 6-inch cubes of 1:2 mortar and electrically coupled to mild steel panels, whose area ranged from 1 to 12 times that of the aluminum alloy. Although the larger steel cathodes drew more current initially, after two weeks' exposure, the galvanic currents were about equal (See Figure 8). After an exposure period of 10 weeks, the panels were similar in appearance. This

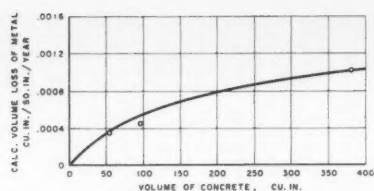


Figure 7—Effect of concrete volume on embedded 3003-H14 alloy panels exposed 8 weeks to room conditions. This curve shows effect of concrete volume on the rate of corrosion of embedded aluminum alloys. Note that the corrosion rate, after a volume of about 100 cubic inches of concrete was reached was not affected appreciably by additional increases in volume. All showed superficial etching.

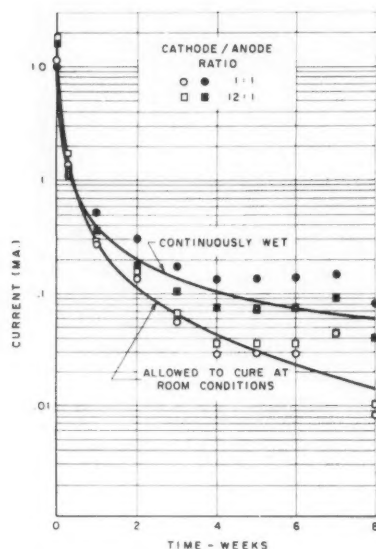


Figure 8—Current flow in aluminum to steel couples embedded in 1:2 mortar for two months. This curve illustrates the effect of cathode area on the current flow between 3003 alloy aluminum and steel embedded in concrete. Little or no current flow differences were noted among concrete blocks which contained increasing area ratios of steel to aluminum. Plotted curves are the currents observed in the blocks which contained the extreme ratios tested both in the normally cured blocks and those which were continuously wet. Current flow studies revealed all ratios to describe the above, low current, curves. This indicates that cathode areas up to 12 times that of the aluminum area cause no acceleration of corrosion. The weight loss data corroborate this indication.

was confirmed by weight loss data (Figure 9), showing that increasing the area of steel up to a ratio of 12 to 1 had little effect on the performance of aluminum. The attack of the coupled panels was found to be less than that observed on an uncoupled control panel. In fact, the specimens of aluminum coupled to steel, even at a 1:12 ratio, showed less attack than did the uncoupled ones (Figure 9). Several other tests have corroborated this phenomenon.

Effect of Cathode Spacing. A test was initiated to determine the effect of cathode distance from 3003

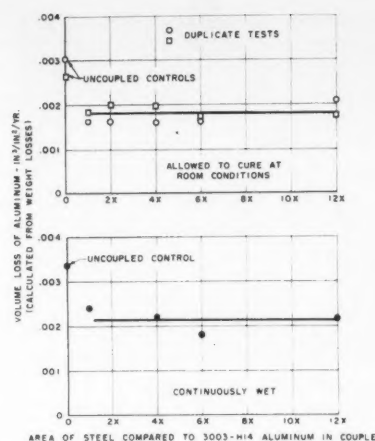


Figure 9—Effect of steel cathode size when coupled to 3003 aluminum embedded in mortar. Effect of cathode area on calculated volume of metal loss of aluminum alloy in concrete is plotted. An increase in steel cathode area to 12 times that of the aluminum panel had no effect on the calculated volume loss of aluminum alloy specimens. Note that the uncoupled panel exhibited higher metal loss than any of those exposed in bi-metal couples. No panel revealed more than superficial general etching.

TABLE 3—Effect of Moisture Retention On 3003 Aluminum Alloy Embedded in Concrete¹

EXPOSURE	Depth of Attack in Mils		Calculated Loss ⁴ (in³/in²/Yr.)
	Average	Maximum	
Six Months to Room Conditions.....	0.7	1.2	0.00052
Six Months Continuously Wet.....	1.2	4.1	0.00120
Three Months Continuously Wet ³	2.9	4.3	.....

Notes:

¹ Concrete used was 1:2:3 mix.

² The forms were removed from the sample 24 hours after pouring the concrete. Thereafter, the sample continuously immersed in water.

³ The concrete in this sample was poured under water and remained so for the duration of the test.

⁴ These values based on weight losses.

aluminum alloy panels. Equal-sized panels of 3003 and mild steel were coupled in 1:2:3 concrete at distances of $\frac{1}{8}$, $\frac{1}{4}$, 1, 2, 3 and 4 inches. Under all conditions, the corrosion of the aluminum alloy specimen was small. It was particularly interesting to note that the corrosion of the aluminum alloy did not increase significantly as the steel was moved from 4 inches to as close as $\frac{1}{8}$ inch from the aluminum alloy (Figure 10). This suggests that the resistances at the metal-concrete interface were, as might be expected, more controlling than the resistance of the mass of concrete.

Effect of Chloride Admixtures. Calcium chloride sometimes is used to lower the freezing point of mortar and concrete during winter and is added also for the purpose of attaining high early strength. Sodium chloride also may be present, perhaps inadvertently, as a contaminant of the water or sand.

Addition of appreciable amounts of calcium chloride or sodium chloride to concrete cured under room conditions had very little effect on the corrosivity of the concrete to aluminum alloys. These tests did

TABLE 4—Effects of Curing Conditions
On the Galvanic Corrosion of 3003 Alloy Embedded in Mortar

Mortar Mix ¹	BI-Metal Couple ²	Depth of Attack in Mils		Calculated Loss (in ³ /in ² /Yr.)
		Average	Maximum	
CURED UNDER ROOM CONDITIONS				
2	None	0.7	1.2	0.00052
2	Al-steel	0.2	0.6	0.00036
2 + NaCl	Al-steel	2.9	11.6 ³	0.00083
CURED UNDER CONTINUOUSLY WET CONDITIONS ³				
2	None	1.2	4.1	0.00120
2	Al-steel	1.8	4.3	0.00097
2 + NaCl	Al-steel	4.3	10.2 ³	0.00163
CURED UNDER CYCLICALLY WET CONDITIONS ⁴				
2	None	0.9	2.1	0.00070
2	Al-steel	0.7	1.1	0.00064
2 + NaCl	Al-steel	4.3	21.7 ⁵	0.00243

¹ One part Portland cement plus 2 parts sand. Where NaCl was added, 3½% of the mix water was employed.

² Specimens 0.064 x 2 x 6 inches of 3003 aluminum and mild steel were used in each block.

³ These blocks were immersed in water 24 hours after pouring.

⁴ These blocks were immersed in water for 24 hours at 30-day intervals.

⁵ Local attack. All other specimens suffered only superficial etching.

show, however, that chlorides may aggravate corrosion, primarily when it is of a galvanic nature. In tests where aluminum was coupled to steel in concrete, no adverse effect developed if the concrete remained reasonably dry after curing; but corrosion did seem to continue if the concrete were periodically or continuously wet. This corrosion may be accelerated by diffusion of chlorides to the local anodes where it tends to break down the protective film on the aluminum.

Effects of Curing Conditions. Concrete is cast and cured under a variety of conditions, ranging from continuously dry to continuously wet and intermittently wet. Tests were conducted to simulate these effects on the galvanic corrosion process.

Six-inch tubes of 1:2 mortar were cast around couples of 3003 aluminum alloy and mild steel panels (2 x 6 x .064-inch). The blocks included, as controls, uncoupled panels of the aluminum alloy and steel. One set was prepared with distilled water and one set was made using 3½ percent sodium-chloride solution in distilled water. Exposure was for six months. These cubes were allowed to cure under: (1) room conditions; (2) continuously wet conditions and; (3) cyclically wet conditions. The continuously wet blocks were cured in water; the cyclically wet cubes were placed in water for 24 hours once each month and for the remaining 29 days held under room conditions.

During the test, the galvanic corrosion currents between aluminum and steel were measured periodically (Figures 11, 12). At the conclusion of the test, the specimens were evaluated by visual and microscopic examination and by weight loss determinations. These data are given in Table 4.

The following conclusions were drawn from this evaluation:

1. In concrete free from chlorides, the aluminum specimens revealed only shallow surface attack of little consequence regardless of the curing conditions

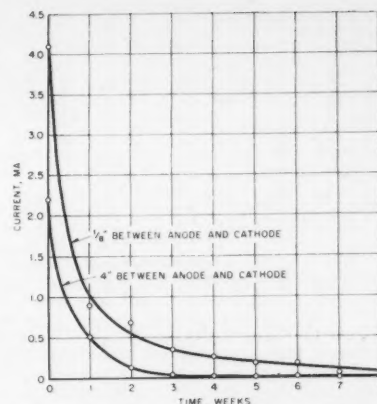


Figure 10—Effect of spacing between 3003-H14 and mild steel panels embedded in concrete. Measured current flow between aluminum alloy and steel in concrete is relatively independent of cathode distance. After the initial setting period of the concrete, incremental cathode distances varying from ½-inch to 4 inches resulted in only small differences in the current flow between aluminum alloy and steel.

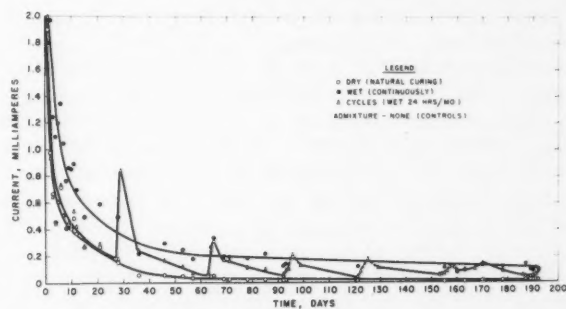


Figure 11—Current flow in 3003-H14 to steel couples embedded in concrete blocks. Corrosion currents, plotted for six months, show intermittent wetting caused inflections in current flow which remained within confines of values obtained with continuously wet concrete after three months. Current flow in the naturally cured concrete dropped to a very low value after two months.

used (Table 4). The aluminum specimens, when coupled to steel, tended to show a little less attack than when not coupled.

2. The presence of appreciable amounts of chlorides in concretes caused somewhat greater attack, mostly of a localized nature. The over-all attack of the aluminum was relatively shallow, however (Table 4).

Mechanism Of Corrosion In Mortar And Concrete

As with most highly alkaline solutions, exposure of aluminum alloys to calcium hydroxide, quicklime, cement slurry or concrete causes dissolution of the natural oxide film. During the first few hours of exposure, a protective film of hydrated calcium aluminate forms over the aluminum alloy and stifles further attack. In the case of 3003 aluminum alloy exposed to calcium hydroxide, the film was found by X-ray diffraction studies to be largely $3 \text{ CaO} \cdot \text{Al}_2\text{O}_3 \cdot 8-12 \text{ H}_2\text{O}$. In a slurry of Portland cement, it was

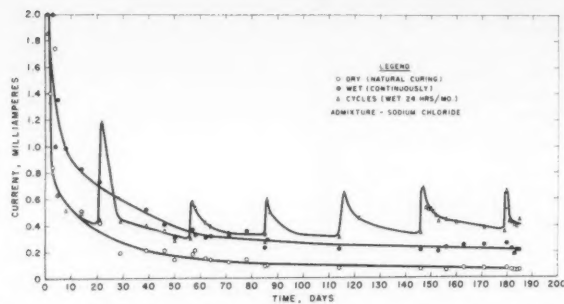


Figure 12—Current flow in 3003-H14 to steel couples embedded in concrete blocks. Intermittent wetting of concrete blocks containing chlorides results in inflections in corrosion currents between aluminum alloy and steel. Contrary to that observed in normal concrete, the inflections significantly exceed current in the continuously wet blocks. It appears that prolonged exposure would prolong this higher magnitude of current flow.

$\text{Al}_2\text{O}_3 \cdot 6 \text{CaO} \cdot 3 \text{SO}_3 \cdot 32 \text{H}_2\text{O}$. The film eventually develops to a point where corrosion is stopped almost completely. As these calcium aluminate films markedly affect the corrosion process, it seemed desirable to determine their effect on the polarization characteristics of aluminum and steel in concrete.

For determination of polarization characteristics, an aluminum-to-steel couple was embedded in a 6-inch cube of mortar. A perforated plastic form (Figure 13) was used to allow continuous water ingress and glass electrodes were pre-set so as to extend to the surfaces of both steel and aluminum. The electrode tips were sealed square and each was equipped with a small hole at the corner. This provided a means to measure unimpeded potentials immediately adjacent to the metal surfaces. All measurements were made against a saturated calomel reference electrode. Natural galvanic current flow was used for the polarization evaluation; this current was incrementally reduced by means of a power resistor. The polarization characteristics were followed over a period of about one month.

Polarization characteristics are illustrated in Figure 14. Initially, the open circuit potential of aluminum (3003) was about -1.5 volts against a saturated calomel reference electrode, and this decreased gradually in the cathodic direction to about -1.3 volts in 576 hours. Steel had an open circuit potential initially of about -0.400 volts, but increased rapidly to about -0.950 volts. Its open circuit potential, as with aluminum, gradually declined over the 576 hour period to about -0.800 volts. The squared ends of the curves in Figure 14 are a qualitative measure of the voltage drop through the mortar (about $2\frac{1}{2}$ inches between panels). As evaluated by the first polarization curves measured after seven hours, the initial corrosion process was largely under cathodic control. As time progressed, the corrosion process changed gradually to one of anodic control. After about three days curing, the cell was under strong anodic control, indicating the formation of a very effective protective film over the aluminum surface. This was further emphasized by the fact that application of a very small external current resulted in rapid anodic polarization of the aluminum as shown in Figure 14. This is substantiated by the summary

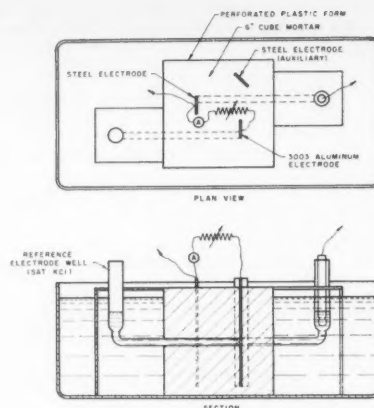


Figure 13—Apparatus for determining polarization. This is the apparatus used to determine polarization characteristics of a 3003-H14 aluminum alloy to steel couple embedded in mortar. The enclosing tank and electrode wells were filled with distilled water to permit measurement of surface potentials on each panel. Potential measurements were made using a saturated calomel reference electrode which was inserted in each of the wells. Simultaneous galvanic current control permitted study of the polarization characteristics.

information in Figure 15, showing that the galvanic corrosion of aluminum decreased, particularly after six hours, to low values.

These findings explain why corrosion of aluminum in concrete (chloride free) did not increase noticeably by increasing the cathode area of steel to a ratio of 12 to 1. In fact, it appears that even much larger ratios of steel to aluminum could be tolerated, because the increased area of steel would increase corrosion of aluminum mainly during the pouring and setting of the concrete only. Beyond this time, the increased area of steel would be expected to have a minor effect. Chlorides in the concrete may alter this situation and require separate study.

Stray Current Effects

Several cases of severe corrosion of aluminum in concrete have been noted either directly or through the literature.⁹ The specific cause for this corrosion has not been fully resolved. In considering the foregoing data and experience, it is unlikely that such attack was the direct effect of the concrete. Furthermore, data given herein indicate that such extensive corrosion could not result from galvanic currents between aluminum and steel. This would be true especially if the concrete were free from chlorides. The presence of chlorides in concrete does tend to aggravate galvanic attack between aluminum and steel, particularly under intermittently or continuously wet conditions. The laboratory tests now available, however, show that such attack would not account for the severe corrosion observed in exposures of less than several years.

It has been shown in tests at the Alcoa Research Laboratories, and elsewhere, that the corrosion of the magnitude encountered in several cases in service could best be explained on the basis of leakage current corrosion, rather than by natural galvanic cor-

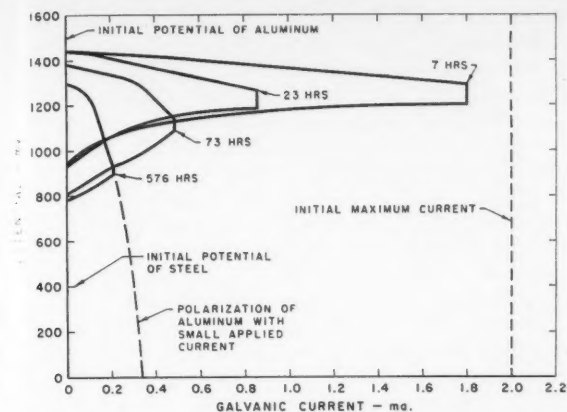


Figure 14—Polarization of aluminum-to-steel panels embedded in continuously wet mortar. Characteristic polarization curves are shown at our time increments. Nature of the curve for the 576-hour increment was apparent from similar curves obtained after exposures of as few as 90 hours. Application of a small external current produced rapid polarization of the aluminum panel in the cathodic direction. The effect is shown by the dotted line. Aluminum alloy used was 3003-H14; steel was bright finished (0.04% carbon) mild steel. All potentials were measured using a saturated calomel reference electrode.

rosion between dissimilar metals. In cases of corrosion of aluminum (or steel) in concrete installations it would be well to suspect leakage currents as one probable cause.

Protective Coatings Sometimes Useful

While aluminum alloys will perform adequately in many applications involving alkaline building products, in certain cases it is desirable to use protective coatings. Definite benefits are obtained from the use of protective coatings to prevent staining, eliminate crevice corrosion, minimize galvanic corrosion, and increase adhesion by decreasing gas evolution at metal interfaces.

Two types of organic coatings are employed commonly on aluminum alloys when used with alkaline building products. These are clear methacrylate lacquers and heavy-bodied bituminous or asphaltic type paints. The lacquer coatings generally are employed where appearance is an important factor. Such applications include windows, framing members, divider strips and other prominent architectural components. The lacquer coatings not only prevent staining and minimize "poultice" corrosion but also preserve the appearance of the aluminum. These coatings also have the advantage of permitting easy removal of spilled mortar, plaster and other materials of construction from the aluminum surfaces.

The heavy-bodied bituminous or asphaltic coatings are effective in protecting aluminum alloys under severely corrosive conditions, such as may arise from unusual "poultice" conditions or galvanic corrosion situations. It is generally recommended that such coatings be employed on aluminum alloys in applications where these conditions are likely to be encountered. Such coatings are relatively inexpensive and well worth the insurance they provide. In addition, they are relatively simple to apply, requiring only that the metal surfaces be free of oil and grease

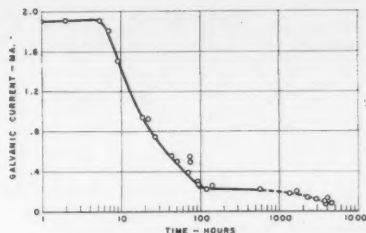


Figure 15—Galvanic current flow between 3003 aluminum and mild steel embedded in 1:2 mortar, continuously wet. This includes a summary of the peak natural galvanic currents obtained in the polarization studies on 3003-H14 aluminum alloy to mild steel couples in mortar. Note that the current flow decreased rapidly after the first six hours of exposure. Extrapolated points shown by the dotted portion of the curve were obtained from other investigations of a similar nature.

deposits. In contrast, the lacquer type coatings require that the metal surfaces be chemically clean for best performance. Proprietary phosphoric acid type cleaning solutions and chemical conversion coatings usually are employed on aluminum alloys for this purpose.

In addition to the coatings described above, temporary protective tapes, greases and strippable coatings also can be used to protect aluminum alloys from the action of alkaline building products. Such protective measures are not recommended for general purposes but only for specific applications because of their inherent characteristics. However, they are satisfactory for many applications.

Summary

Results of many laboratory tests and extensive service experience have demonstrated that aluminum alloys are suitable for use with a wide variety of alkaline building products. As is the case in many other environments, the corrosion of aluminum alloys when used with these alkaline products is superficial only and is self-limiting in nature. This performance, as demonstrated by polarization studies, results from the formation of highly protective films on the metal surfaces.

Unusual circumstances in installations involving aluminum alloys and alkaline building products sometimes may require special consideration. Chlorides, dissimilar metals, leakage currents, differential aeration effects or combinations of these factors may necessitate the use of protective measures. Information included in this paper should be of assistance in resolving these problems in a practical manner.

Acknowledgment

Appreciation is expressed to G. C. English for his helpful suggestions and contributions, particularly with respect to the polarization studies in the investigation of the mechanism of corrosion in mortar and concrete.

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DISCUSSION

Question by Robert W. Martel, Linde Air Products Co., Tonawanda, N. Y.:

What electrolytic mechanism was responsible for about 100 microamperes of current flowing in the steel-aluminum couple in dry concrete after 180 days?

Reply by C. J. Walton, F. L. McGeary and E. T. Englehart:

The "dry" concrete referred to concrete that was not continuously or periodically wetted subsequent to pouring, but was cured and stored at room conditions. The curing process of concrete, which involves the gradual expulsion of water, lasts at least a year. Thus, the "dry" concrete undoubtedly contained some moisture that acted as an electrolyte for galvanic currents. However, the rate of galvanic attack was exceedingly small. Calculations show that the expected life of a specimen 1/16-inch thick would be in excess of 1000 years under these conditions of current flow.

Comments by Hugh P. Godard, Aluminium Laboratories, Ltd. of Canada, Kingston, Ont.:

Our experience with Al embedded in concrete parallels that reported, including the influence of Al-steel couples, chlorides and moisture. (cf HPG et al Eng Journal (Montreal).⁸ The major corrosion hazard of Al in contact with concrete is not embedment, but line contact as with an aluminum conduit affixed tightly to a concrete wall.

I would also put in a plea for the use of mpy for reporting corrosion rates.

Reply by C. J. Walton, F. L. McGeary and E. T. Englehart:

Although aluminum alloys have provided consistently good performance when set in concrete, the placement of aluminum alloys against pre-cast concrete represents a situation that is somewhat different. Differential aeration or oxygen concentration cell effects are more likely to be encountered under these conditions. In addition, other factors such as wetting, drying, or the presence of extraneous chemical contamination may cause a wide variation in the corrosivity of the environment.

In some cases, it is recommended that protective coatings be employed to prevent the possible occurrence of corrosion from factors such as these while in others the use of protective coatings is not necessary. The advisability of using such protective coatings under unusual conditions has been discussed in the paper. Actually there are many practical applications of aluminum alloys in service in which satisfactory performance is being obtained without the use of protective coatings between aluminum contacting concrete.

Regarding methods to express rate of corrosion, the conversion of weight loss data into penetration as "mils per year" does have the advantage of simplicity. This is also its disadvantage, for unless the corrosion is uniformly distributed the calculated mils per year may not provide a realistic value. When corrosion is not uniform, as is more often the case, rate of penetration based on actual measured depths of attack always will be greater and likely much greater than that calculated from weight loss data.

The term "cubic inches per square inch per year" ($\text{in}^3/\text{in}^2/\text{yr}$) is used at the Alcoa Research Laboratories to convert weight loss data into volume of metal lost by corrosion. This provides a means for comparing various alloys or metals of different densities on the basis of the total corrosion that had taken place, regardless of its distribution. If the corrosion is non-uniform, as is often the case, the rate of penetration and effect of corrosion on certain mechanical properties, as tensile strength, must be established by measurements other than loss in weight. The preceding term readily converts to mils per year, having the same numerical values, and could be used to provide rate of penetration values if corrosion were uniform in nature.

It would be highly desirable to standardize on a term to express corrosion rates based on weight loss data; it is understood that the NACE is about to do this.

Any discussions of this article not published above
will appear in the June, 1958 issue

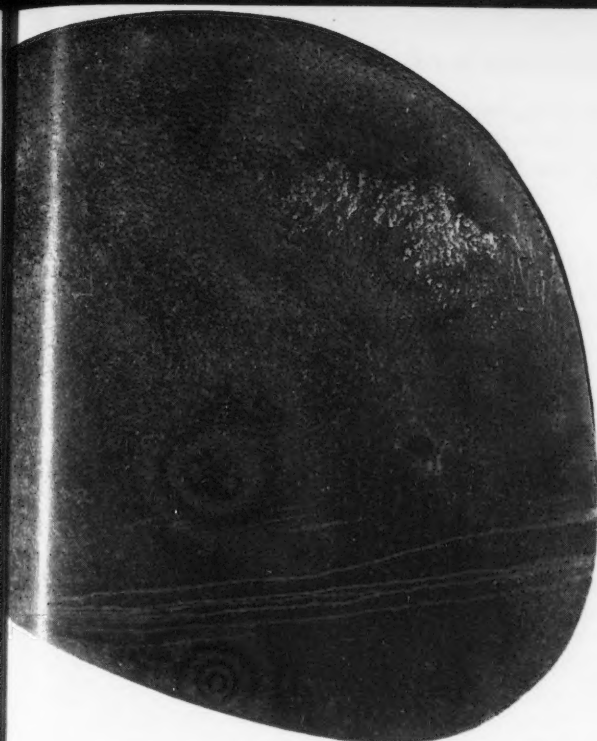


Figure 2—Corrosion of forward propeller on M.V. Abegweit.

J. H. GREENBLATT—With Chemistry and Corrosion Section, Naval Research Establishment, Dartmouth, Nova Scotia. He is occupied with corrosion and electrochemical studies. From 1943 to 1946 Dr. Greenblatt was at the Internal Ballistics Research Laboratory, Valcartier, Quebec. He has an MSc in physical chemistry from Dalhousie University and a PhD in physical chemistry from McGill University, 1948.



Abstract

Measurement of polarization characteristics of steel coupons subjected to the usual treatments given ship plating indicate that cathodic depolarization is the major factor influencing the corrosion observed. At low temperatures in oxygenated water considerable anodic polarization occurred which would tend to mitigate corrosion in low temperature oxygenated waters. Results are discussed in terms of observed corrosion patterns on the hulls of vessels operating in ice.

8.9.5

Introduction

INSPECTION of ice-breaking vessels in drydock has shown that this type of ship experiences severe corrosion of the underwater hull. The corrosion takes the form of severe and general pitting, corrosion of welds, corrosion of ferrous propellers and on ice breakers fitted with propellers at the bow, very severe corrosion of plating, rivet heads and welds at the front end of the ship. Examples of such corrosion are shown in Figures 1 to 3.

In normal service these ships undergo periods of

Polarization in the Corrosion of Ice Breakers*

By J. H. GREENBLATT

operation when the underwater hull is essentially bare because the underwater paint is scoured off by ice. Moreover, ice breakers with bow propellers are continually riding into a wake of stirred oxygenated water when this propeller is used. The unusually severe corrosion seen on these vessels could be caused by depolarization effects that are occurring due to the conditions under which these vessels operate. The effect of cathodic depolarization would be expected to be of major importance on the basis of the general principles discussed by Akimov,¹ Evans,² Todt,³ Uhlig⁴ and others. It was felt, however, that the effect of polarization changes occurring on steel subjected to the various surface treatments given ships' plate, should be investigated to determine the magnitude of the effects occurring and to determine if any insight could be obtained concerning the corrosion patterns observed. Accordingly the anodic and cathodic polarization curves were obtained in sea water in the laboratory for steel coupons given various treatments.

Experimental

The technique used for obtaining the polarization curves was a standard one discussed by other authors.^{1,2,3,4} Steel coupons were mounted in pairs as anode and cathode in a sink continuously supplied with fresh sea water and the closed circuit potential of each was measured with a silver-silver chloride probe electrode, held close to the steel surface at various current densities ranging from 0 to 34 mA/sq. ft. Edges and back faces of the coupons were masked off and the exposed area was 0.056 sq. ft. Measurements were made at 3 C, 20 C and 48 C in unstirred sea water, sea water stirred by hydrogen bubbling and sea water stirred by vigorously bubbling oxygen through it. The sea water supply in the Naval Research Laboratory is obtained from Halifax Harbor and is pumped into the laboratory and would normally be air saturated.

* Submitted for publication May 1, 1957.



Figure 1—(Top) Corrosion on bottom of M.V. Abegweit. Photograph of port bow. Note general deep pitting, severe corrosion on welds and pitting of rivet heads. Smooth steel coupon shown has been welded on to gauge the effectiveness of the presently fitted cathodic protection system.

Figure 3—(Middle) General corrosion and corrosion of welds on the starboard stern of H.M.C.S. Labrador.

Figure 4—(Bottom) General pitting of plating and welds on port midship section of Bonavista.

The coupons were subjected to the following treatment before measurements were made: Sandblasting, sandblasting followed by rusting by alternate immersion in sea water, sandblasting followed

by phosphating, pickling, pickling followed by phosphating, and mill scaled steel as received from the rolling mills. A set of painted and scored coupons was used also.

Results

The recorded values of closed circuit potential were plotted against current strength, and at low and moderate current densities they could be approximated by straight lines as is the standard practice. The slopes of these lines would then be a measure of the polarization occurring.

Cathodic polarizations obtained this way are shown in Table 1. Because of the assumption that the voltage curves are linear the polarization values quoted should be considered relative to each other rather than absolutely. It is seen from Table 1 that for essentially bare steel, e.g. sandblasted and pickled with no subsequent treatment the polarization in unstirred and stirred non-oxygenated water is maximum between 15-20 C, is minimal at high temperatures and intermediate in value at low temperatures. When cleaning was followed by a subsequent treatment such as phosphating, painting, rusting, etc., and with mill scaled panels, the maximum at intermediate temperatures disappeared and a gradual increase in polarization occurred in dropping from 50 to 3 C. In all these latter cases the "bare" surface is covered with a film, either oxide or phosphate as the scoured and painted panel was phosphated prior to painting. No further marked effects of pretreatment can be seen, although the sandblasted panels show up more or less as a group. The effect of stirring by hydrogen at high temperature produces a general increase in polarization.

Anodic polarizations are shown in Table 2. They are smaller than cathodic polarizations and again the sandblasted panels appear as a group. Marked anodic polarization occurs in the presence of oxygen at low temperatures.

Discussion of Results

The above results can be applied to explain the observations on drydocked ships that have been operating in ice. When the hull is bare and the ship is at rest, cathodic polarization is greatest for the case where a rust film or other film such as a phosphate film is present on the steel. The anodic polarization under these conditions is low. When the ship gets underway, cathodic depolarization occurs and this is even more marked when the ships are in oxygenated water as when using the forward propeller or when backing off ice into oxygenated water. Under these conditions, however, marked anodic polarization occurs and this tends to mitigate corrosion. An example of this is seen in Figures 4 and 5 of the motor vessel Bonavista. The rudder area, which would be in the stream of oxygenated water, is in good condition while the bare forward areas are severely pitted. This is contrary to the more usual experience with ships operating in warmer waters when severe rudder corrosion is experienced.

In intermediate temperature waters, depolarization by stirring and oxygen would cause very large in-

creases in the corrosion current, the increase being greater in the case of oxygenation. Because anodic polarization is practically zero, severe corrosion would be expected to occur on bare steel area, especially when the forward propellers are used for maneuvering. At high temperatures greater corrosion would be expected because of lower cathodic polarization when at rest and even lower cathodic polarization when underway. Anodic polarization is very low at high temperatures.

If the steel areas are continually scoured by ice so that no film of corrosion product can form on the surface, then because polarization at low temperatures is lower than polarization at intermediate temperatures when at rest and when underway, (corresponding to the stirred but non-oxygenated condition), greater corrosion would be observed when comparing the corrosion on a ship in ice to one operating at normal temperatures but suffering paint loss due to mechanical abrasion. Actual experience bears out this prediction.

In the operation of the H.M.C.S. Labrador the ship is in northern waters in ice during the summer and then returns to Halifax in the fall, where it is berthed all winter. The data of Tables 1 and 2 suggest that the trip south provides the optimum conditions for corrosion, bare rusted steel in reasonably warm stirred water and that the tying up at Halifax during the fall when water temperature is at its maximum would also lead to severe corrosion. Corrosion can be controlled by either a ship mounted or towed cathodic protection system. The latter is suggested because it is not yet definitely known if a ship mounted system could withstand severe ice action. The towed system would combine the features of a slung anode system when in port, which is now used and a possible short life, ship mounted system which would last until lost in ice.

With the car Ferry M.V. Abegweit the period of severest corrosion has been shown by observation to be between baring of the hull in January and docking in May. It had also been observed during

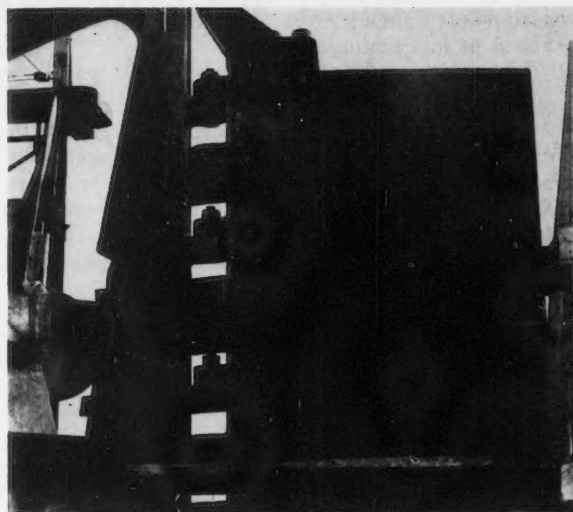


Figure 5—Rudder of Bonavista.

an October drydocking of the ship that severe corrosion can also occur when the ship is operating in warmer summer waters. The corrosion occurred at holidays in the paint and was severe because this ship uses its forward propeller for maneuvering. The data Tables 1 and 2 indicate that severe corrosion should occur when using the forward propeller in warm waters.

This vessel is presently protected with a short-life magnesium anode system designed to last from drydocking time until the loss of the anodes in ice. After the loss of its anodes the ship is protected when in port by slung jetty anodes. Because of continual travelling and maneuvering and the fact that the ship is tied up 60 per cent of its time, a towed anode system is not considered feasible.

Data are also in agreement with the observation that less current is required to polarize cathodically protected ships in ice-free winter waters than in summer because the data show that with a film on

TABLE 1—Cathodic Polarization Volts/Milliamperes

TREATMENT	Temp °C	No Stirring	Stirring With H ₂	Stirring With O ₂
Sandblasted	3-5	0.088	0.018	0.003
	15-20	0.155	0.075	0.011
	45-50	0.023	0.048	0.0054
Sandblasted Sea Water Rusted	3-5	0.095	0.0097	0.012
	15-20	0.024	0.097	0.007
	45-50	0.018	0.025	Not detectable over current range used
Sandblasted and Phosphated	3-5	0.081	0.075	0.015
	15-20	0.017	0.035	0.008
	45-50	0.025	0.052	0.0098
Pickled	3-5	0.035	0.024	0.03
	15-20	0.048	0.044	0.01
	45-50	0.017	0.024	0.011
Pickled and Phosphated	3-5	0.26	0.0097	0.043
	15-20	0.22	0.025	0.024
	45-50	0.038	0.031	0.0068
Mill Scale	3-5	0.26	0.0097	0.043
	15-20	0.23	0.12	0.015
	45-50	0.038	0.084	0.013
Sandblasted Phosphated Painted and Scored	3-5	6.0	0.70	0.59
	15-20	22	0.59	1.0
	45-50	0.5	1.20	0.38

TABLE 2—Anodic Polarization Volts/Milliamperes

TREATMENT	Temp °C	No Stirring	Stirring With H ₂	Stirring With O ₂
Sandblasted	3-5	-0.0087	-0.016	-0.0382
	15-20	-0.0087	-0.012	0
	45-50	0	0	0
Sandblasted and Rusted in Sea Water	3-5	-0.011	-0.0077	-0.020
	15-20	-0.0077	-0.010	0
	45-50	0	0	-0.0077
Sandblasted and Phosphated	3-5	0	-0.029	-0.024
	15-20	-0.0077	-0.010	-0.0097
	45-50	-0.0065	-0.012	0
Pickled	3-5	-0.025	-0.0175	-0.067
	15-20	-0.18	-0.02	-0.012
	45-50	0	-0.0075	0
Pickled and Phosphated	3-5	-0.022	-0.038	-0.060
	15-20	-0.025	-0.0087	-0.0085
	45-50	0	-0.0087	-0.0085
Mill Scale	3-5	-0.037	-0.032	-0.045
	15-20	-0.010	-0.020	-0.010
	45-50	-0.013	-0.020	None
Sandblasted, Phosphated Painted and Scored	3-5	-0.340	-0.370	-0.122
	15-20	-0.175	-0.071	-0.250
	45-50	-0.044	-0.035	-0.033

the unpainted metal areas cathodic polarization is greatest at low temperatures.

Conclusions

Measurements of anodic and cathodic polarization indicate that higher temperatures and oxygenation are the most favorable conditions for corrosion. Corrosion at low temperatures would be most severe in cold oxygenated water, except for the counteracting effect of marked anodic polarization.

Acknowledgments

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Any discussions of this article not published above
will appear in the June, 1958 issue

TECHNICAL PAPERS ON CORROSION WELCOMED

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Inhibiting Effect of Hydrofluoric Acid In Fuming Nitric Acid on Liquid and Gas Phase Corrosion of Several Metals*

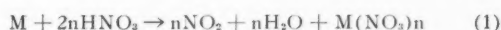
By DAVID M. MASON,⁽¹⁾ LOIS L. TAYLOR⁽²⁾ and JOHN B. RITTENHOUSE⁽³⁾

Introduction

IN A PREVIOUS study of the chemical processes of corrosion and thermal decomposition,¹ samples of fuming nitric acid (FNA) of various initial compositions were stored in sealed pressure vessels constructed of the particular metal of interest in order to simulate actual storage conditions. It was found that aluminum alloys and the Cr (18 weight percent)-Ni (8 weight percent) class of stainless steels were passivated by HF in FNA. In these tests the metal surface was exposed simultaneously to liquid and gas phase. In the present investigation the primary objective was to study independently the corrosion process by each phase in thermally stable FNA containing from 11 to 13 percent⁽⁴⁾ NO₂ and 2 to 4 percent H₂O.

To emphasize the effects of corrosion by each phase independently, small samples were exposed to either liquid or gas phase of FNA contained in pressure-tight vessels lined with Teflon. Factors such as temperature, composition of FNA, storage time, and metallurgical condition of the metal were not varied over a wide range in this particular study; instead, general corrosion behavior was measured.

The irreversible corrosion of certain metals has been shown¹ to proceed in the following over-all fashion:



where M represents a metal of valence *n* in the oxidized state. With certain metals it was found that quantities of HF of about 0.4 to 0.6 percent in FNA are capable of causing passivation of the surface with a resultant marked decrease in corrosion.

It has been established¹ that the passivation process with aluminum alloys is connected with the formation of a slightly soluble aluminum-fluorine compound on the surface of the metal. With steel alloys, the nature of the passivation process has not been definitely established although, in the case of the 18-8 stainless steel alloys, iron, chromium, and nickel as well as fluorine are found in the passivating

Abstract

Measurements were made at 130 degrees F of the extent of corrosion of several metals exposed to the liquid and the gas phase of thermally stable nitric acid containing 11 to 13 weight percent nitrogen dioxide and 2 to 4 weight percent water with and without hydrofluoric acid added as a corrosion inhibitor. Liquid-phase corrosion of the following metals was readily inhibited by hydrofluoric acid in fuming nitric acid of this composition: aluminum alloys 2S-0 (1100), 14S-T6 (2014-T6), 17S-T4 (2017-T4), 24S-T4 (2024-T4), 61S-T6 (6061-T6), and 75S-T6 (7075-T6); aluminum 2S-O welded to 356; and chromium-nickel steels 302, 303, 304, 321, 347, Armco 17-7PH, and Uniloy 19-9DL and 19-9DX. Carbon steel C1020 and chromium alloy steels 4130, 410, 430, and 446 having intact natural metal oxide films, which were formed in moist air, were inhibited by hydrofluoric acid. Corrosive attack of these steels without the oxide film, however, was aggravated by the presence of hydrofluoric acid in fuming nitric acid, the corrosion becoming more extensive the lower the chromium content of the steel. Commercially pure lead was inhibited by hydrofluoric acid, whereas pure chromium, Nickel-A, tantalum, and titanium alloys 75A and 130A were either only slightly inhibited or showed corrosion rates which actually were increased by presence of hydrofluoric acid in fuming nitric acid. Inhibition of gas-phase corrosion was found to occur readily in the case of the following metals tested: steels 303, 410, 430, and 446 and aluminum 61S-T6. Gas-phase corrosion of steels 4130 and 1020 was usually aggravated by hydrofluoric acid. Exposure of aluminum 61S-T6 and stainless steel 347 to fuming nitric acid with a repeated cycling of temperature between 70 and 160 degrees F was found not to impair the inhibiting effect of hydrofluoric acid on gas and liquid-phase corrosion of these metals.

A few tests of the liquid and gas-phase corrosion of aluminum 61S-T6 and steels C1020 and 347 by nitrogen dioxide at 130 degrees F were also made, and this medium was found in general to be much less corrosive than fuming nitric acid. 4.3.2

coating. It should be pointed out that, because of the nature of the passivation process with aluminum alloys (and possibly with stainless steel alloys), the FNA must become completely saturated with respect to fluoride of the metal before the passivating layer is completely in stable equilibrium. For containers with a ratio of surface to liquid volume of about 4 inches⁻¹ or less, 0.4 to 0.6 percent HF is sufficient to ensure liquid-phase passivation with these alloys. Before passivation can occur, either the corrosion process of Equation (1) must proceed until enough metal is dissolved to permit the metal fluoride to precipitate, or the solution must have been saturated by adding the metal fluoride. The detailed physico-chemical factors related to the passivation process are being thoroughly investigated. The aluminum

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⁽⁴⁾ Compositions are expressed on a formal weight percentage basis throughout this report.

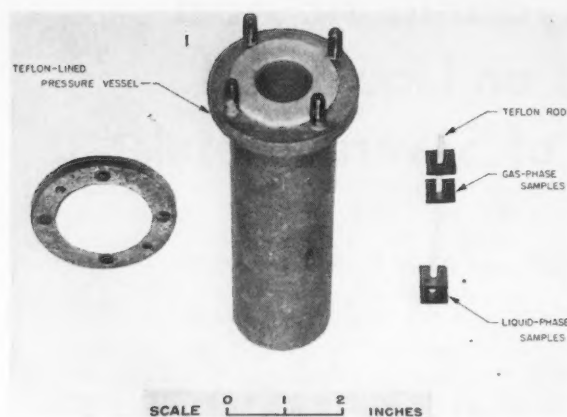


Figure 1—Corrosion-testing equipment.

TABLE 1—Chemical Analyses of Fuming Nitric Acid Samples

Composition (Weight Percent)	Inhibited FNA	Uninhibited FNA
HNO ₃	83.5	85.2
NO ₂	13.2	11.9
H ₂ O.....	2.8	2.8
HF.....	0.5	0
Al(NO ₃) ₃	—	0.05
Fe(NO ₃) ₃	—	0.02

alloys studied were in general passivated by HF in FNA. Stainless steels of the 18-8 class containing both chromium and nickel are generally passivated, whereas chromium alloy steels 4130, 410, 430, and 446 and carbon steel C1020 are passivated only under specific initial surface conditions.

Equipment, Methods, and Materials

A pressure-tight vessel constructed of Al 61S-T6 and lined with Teflon⁽⁵⁾ was used in the corrosion tests. This experiment is shown in Figure 1. The Teflon liner was 1.0 inch in inside diameter and 5.0 inches in depth. Metal samples about $\frac{1}{32}$ inch thick in the shape of either round disks $\frac{3}{4}$ inch in diameter or square pieces $\frac{1}{2}$ inch wide were used. Holes $\frac{1}{8}$ inch in diameter were drilled in the center of the samples, which were then forced on the $\frac{1}{8}$ inch diameter Teflon rod. By locating the samples at the proper position along the rod, the sample could be exposed to either gas or liquid phase. The polished metal samples were cleaned with acetone before immersion in the FNA to ensure absence of oil films on the surface. With low-alloy and plain carbon steels it was found that passivation occurred only when the surface contained an oxide film resulting from exposure to humid air. Thus samples in this category were stored in moist air for seven days after cleaning.

With the area and density of the sample known, the depth of corrosion was determined by measuring the weight lost by the sample during exposure. Any loosely adhering coating was removed by a rubber eraser before the final weighing was made.

For most of the tests a constant-temperature bath

maintained within ± 0.2 degrees F of 130 F was used. For one series of tests a mercury regulator with a contact wire which was mechanically driven in such a fashion as to impart a sinusoidal temperature fluctuation to the water bath was used. The temperature fluctuated between 70 and 160 degrees F and back to 70 F in a 24-hour period. At any time the temperature was within 0.5 degrees F of an exact sinusoidal temperature profile.

Commercial-grade FNA manufactured by the Hercules Powder Company at Pinole, California, was used in the tests. Chemical analysis of the samples of FNA used with and without HF is given in Table 1. The composition of the FNA after the corrosion tests was checked periodically although the results are not presented herein. The percentage of conversion of HNO₃ by corrosion was, on the average, less than about 5 percent; however, when corrosion rates were extremely high, the conversion of HNO₃ was correspondingly high. For the few tests of corrosion by NO₂, a dried sample (99 percent grade) supplied by Matheson, Coleman, and Bell was used.

Corrosion of Aluminum Alloys by Fuming Nitric Acid

The results of corrosion tests on several aluminum alloys show that these materials are very effectively passivated against the corrosive action of liquid and gas phase FNA by the presence of about 0.5 percent HF in the FNA. These results are summarized in Figure 2.

Corrosion of Unwelded Aluminum Alloys

For all the aluminum alloys tested, the presence of HF in FNA inhibited liquid and gas phase corrosion. Liquid phase corrosion at 130 degrees F of aluminum alloys 2S-O, 14S-T6, 17S-T4, 24S-T4, 61S-T6 and 75S-T6 was measured; gas phase corrosion of aluminum 61S-T6 also was measured. The results of these corrosion tests are summarized in Figure 2 and Table 2. The data show that, when about 0.5 percent HF was present in the FNA, marked passivation occurred in both the liquid and the gas phase. It is of interest to note from Figure 2 that the liquid phase corrosion rates of all the unwelded aluminum alloys are similar in magnitude; thus the different chemical composition of these alloys does not measurably affect their corrosion behavior.

From the data in Table 2 it is seen that the calculated linear average corrosion rates for the gas phase continuously decrease with an increase in time, whereas the corresponding rates for the liquid phase reach a maximum. These data show the potential error in utilizing linear average corrosion rates obtained for one storage period to calculate expected extent of corrosion at a different time.

It is seen that the gas phase corrosion rates for Al 61S-T6 are lower than the liquid phase rates except at the initial stages of corrosion. Evidently the passivating effect on corrosion by both phases is due to the presence of HF in the FNA. The corrosion rates obtained by the gravimetric technique with

(5) Teflon is a solid polymerized fluorinated hydrocarbon manufactured by du Pont de Nemours Co. This material is very resistant to FNA.

the sample exposed to the liquid or the gas phase are similar to those obtained by chemical analysis of the FNA contained in metal bombs exposed predominantly to either the liquid or the gas phase.¹ Actually the samples exposed to inhibited FNA demonstrated an increase in weight due to the passivating layer. Thus the accuracy of these measurements is low though the order of magnitude is correct.

Anodized aluminum 14S-T6 and 2S-T6 gave a measured value for the extent of corrosion in uninhibited liquid phase FNA of about half that of corresponding unanodized alloys for a storage period of 30 days. However, pitting was observed in both anodized and unanodized samples, and the general appearance was similar. The effect of anodizing in reducing corrosion probably occurs mainly in the initial stages of corrosion; after prolonged storage this initial behavior becomes masked.

Corrosion of Welded Al 356 and Al 2S-O

The passivating effect of HF on the liquid phase corrosion of welded aluminum alloys 356 and 2S-O is shown in Figure 2 and Table 2. The average corrosion rates for Al 356 welded to 2S-O and also welded to itself with 43S or 2S-O rod is seen to be reduced by HF in FNA. Since these corrosion rates were obtained by gravimetric technique, high localized corrosion effects such as pitting or knife-line attack at the weld-parent metal junction are not necessarily revealed. Visual inspection of the samples indicated, however, that no localized corrosion occurred in either the parent metal or the weld.

Corrosion of Steel Alloys by Fuming Nitric Acid

The passivation of steel alloys by HF in FNA is not as general as that of aluminum alloys. As is evident from the summary of corrosion data in Figure 3, samples of the Cr (18 percent)-Ni (8 percent) class (302, 303, 304, 321, 347, Armco 17-7PH, and Uniloy 19-9DL and 19-9DX) usually are passivated by HF in both liquid and gaseous FNA. However, with alloys in this class such as Uniloy 19-9DL which in certain heat treatments are subject to chro-

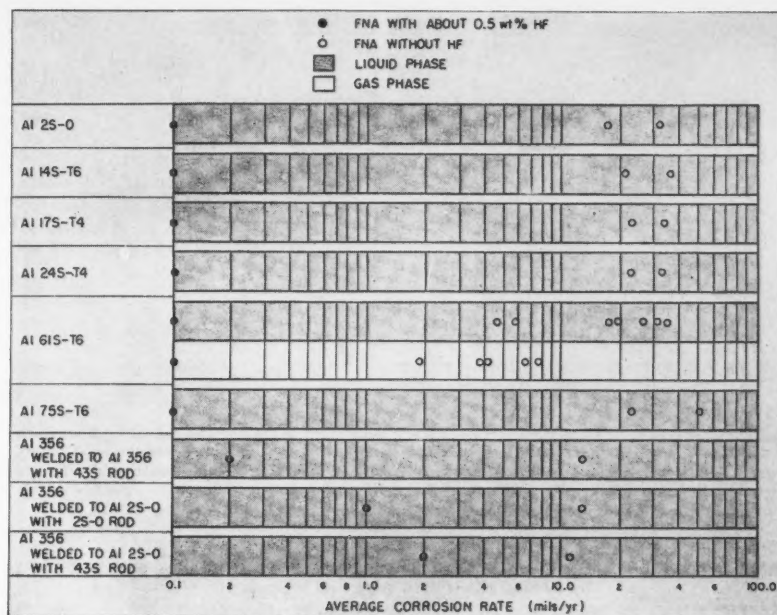


Figure 2—Summary of data on corrosion of aluminum alloys at 130 F by fuming nitric acid with and without HF.

TABLE 2—Summary of Data^a on Corrosion of Aluminum Alloys at 130 F by Fuming Nitric Acid With and Without HF

Alloy	CORROSION DEPTH (mils)				AVERAGE CORROSION RATE (mils/yr.)			
	With About 0.5 Weight Percent HF		Without HF		With About 0.5 Weight Percent HF		Without HF	
	Gas	Liquid	Gas	Liquid	Gas	Liquid	Gas	Liquid
Al 2S-O	—	<0.008 ^b	—	1.4 ^c 0.92 ^d	—	<0.1 ^b	—	17 ^e 32 ^d
Al 14S-T6	—	<0.008 ^b	—	1.7 ^c 1.0 ^d	—	<0.1 ^b	—	21 ^e 36 ^d
Al 17S-T4	—	<0.008 ^b	—	1.9 ^c 0.86 ^d	—	<0.1 ^b	—	23 ^e 30 ^d
Al 24S-T4	—	<0.008 ^b	—	1.9 ^c 0.95 ^d	—	<0.1 ^b	—	23 ^e 33 ^d
Al 61S-T6	<0.008 ^e	<0.008 ^b 0.008 ^c	0.13 to 0.15 ^f 0.20 to 0.21 ^g 0.21 ^h	0.09 to 0.11 ^c 1.94 to 2.82 ^b 0.98 ^d 1.4 to 1.6 ^e 1.6 ^e	<0.1 ^e	<0.1 ^b 0.1 ^c	3.8 to 4.1 ^g 6.6 to 7.6 ^f 1.9 ^h	4.6 to 5.8 ^f 17.7 to 25.7 ^b 20 ^e 26 to 31 ^g 34 ^d
Al 75S-T6	—	<0.008 ^b	—	1.9 ^c 1.4 ^d	—	<0.01 ^b	—	23 ^e 50 ^d
Al 356 welded to Al 356 with 43S rod	—	0.016	—	1.07 ^e	—	0.2 ^b	—	13 ^e
Al 356 welded to 2S-O with 2S-O rod	—	0.08 ^b	—	1.07 ^e	—	1 ^b	—	13 ^e
Al 356 welded to 2S-O with 43S rod	—	0.16 ^b	—	0.90 ^e	—	2 ^b	—	11 ^e

^a Each of the seven tests refers to corrosion measurements made on samples in one vessel.

^b Test 1 continued for 30 days.

^c Test 2 continued for 30 days.

^d Test 3 continued for 15 days.

^e Test 4 continued for 40 days.

^f Test 5 continued for 7 days.

^g Test 6 continued for 19 days.

^h Test 7 continued for 40 days.

mium depletion near the grain boundaries,^{2,3} the passivation process is effective only if the sample has not undergone intergranular corrosion prior to being exposed to FNA containing HF. Carbon steel

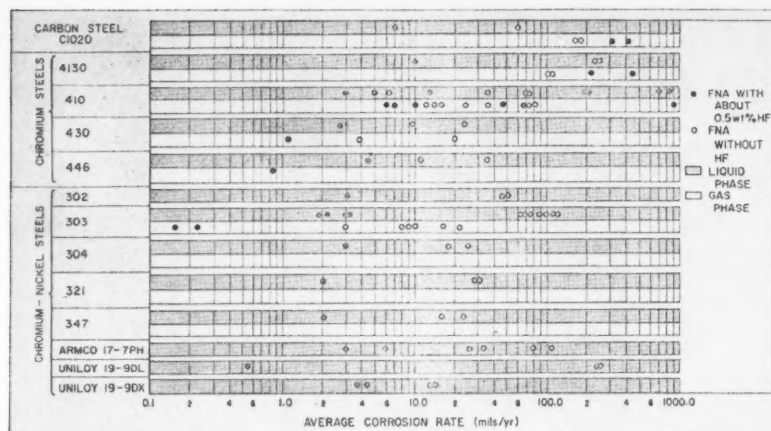


Figure 3—Summary of data on corrosion of steel alloys at 130 F by fuming nitric acid with and without HF.

TABLE 3—Summary of Data^a on Corrosion of Carbon Steel and Chromium Steels at 130 F by Fuming Nitric Acid With and Without HF

Alloy	Oxide Film	CORROSION DEPTH (mils)				AVERAGE CORROSION RATE (mils/yr.)			
		With About 0.5 Weight Percent HF		Without HF		With About 0.5 Weight Percent HF		Without HF	
		Gas	Liquid	Gas	Liquid	Gas	Liquid	Gas	Liquid
C1020	Present	(0.57 to 0.74) ^b	0.01 ^b	(0.31 to 0.35) ^c	0.11 ^c	(309 to 406) ^b	7 ^b	(168 to 189) ^c	60 ^c
4130	Present	(0.40 to 0.85) ^d	0.02 ^d	(0.19 to 0.22) ^e	(0.44 to 0.48) ^e	(210 to 465) ^d	10 ^d	(105 to 121) ^e	(241 to 260) ^e
410	Present	0.06 ^f 0.08 ^f	0.02 ^f 0.04 ^f	0.3 ^g 0.96 ^g	1.7 ^g 0.3 ^g	7 ^f 10 ^f	3 ^f 5 ^f	36 ^g 12 ^g	205 ^g 36 ^g
	Absent	4.2 ^h 6.2 ^h	19 ^h 19 ^h	1.4 ⁱ 2.2 ⁱ	6.3 ⁱ 6.6 ⁱ	47 ^h 69 ^h	210 ^h 200 ^h	16 ^{h,i} 24 ^{h,i}	70 ^{h,i} 73 ^{h,i}
430	Absent	0.02 ⁿ	0.06 ⁿ	0.38 ^k 0.16 ^m	0.18 ^k 0.99 ^m	1.2 ⁿ	2.9 ⁿ	20 ^k 3.9 ^m	9.4 ^k 24 ^m
446	Absent	0.016 ^p	0.09 ^p	—	0.67 ^l 0.45 ^l	0.8 ^p	4.6 ^p	—	35 ^l 11 ^l

^a Each of the twelve tests refers to corrosion measurements made on samples in one vessel.

^b Test 1 continued for 16 hr.

^c Test 2 continued for 16 hr.

^d Test 3 continued for 16 hr.

^e Test 4 continued for 16 hr.

^f Test 5 continued for 3 days.

^g Test 9 continued for 3 days.

^h Test 11 continued for 31 days.

ⁱ Test 10 continued for 31 days.

^j Test 6 continued for 7 days.

^k Test 7 continued for 15 days.

^l Test 12 continued for 7 days.

^m Test 5 continued for 7 days.

C1020, low-alloy steel 4130 (containing 1 percent Cr), and chromium steel 410 (containing 12 percent Cr), which previously were reported to be unpassivated by HF in FNA,¹ have been subsequently found, under certain carefully controlled surface conditions, to be at least temporarily passivated in the liquid phase. It is found that to produce passivation, an unbroken oxide film formed in moist air must be present on the surface of the metal upon exposure. The mechanism of passivation of steel alloys in general presently is being investigated. Chromium steels 430 (containing 15 percent Cr) and 446 (containing 25 percent Cr) are more readily passivated, for with increasing Cr content it appears that the conditions appear to be decreasingly critical. Carbon steels and steels having a Cr content of less than 15 percent are not in general recommended for use with uninhibited FNA, nor are they recommended

with inhibited FNA until more of the factors concerning marginal passivation are established. The ease of passivation appears to depend on the total Cr and Ni content of the steel, passivation being improved by the combination of both these elements in amounts approaching the 18-8 class of steels.

Carbon Steel C1020

Steels (such as C1020) which contain no Cr or Ni are temporarily passivated by HF in FNA when an oxide is initially present on the surface of the metal. This behavior has not been explained although it is possible that some iron oxyfluoride may comprise the coating. The results of the tests are summarized in Figure 3 and Table 3. In the tests reported herein the gas phase corrosion rates are increased by the presence of HF in FNA although some recent tests have shown isolated cases of inhibition. The conditions necessary for reproducing this inhibition have not been established. When the oxide film is destroyed, the liquid phase corrosion rates are aggravated by HF and the FNA. It was found that if the surface of the steel was polished just before immersion in FNA, rapid darkening of the metal occurred at room temperature in FNA both with and without HF. Attack of these samples was extensive upon storage at 130 degrees F for one day and was particularly aggravated in

the FNA with HF. If the coating which formed on the metal because of exposure to moist air at about 70 F for at least 48 hours after polishing was present upon immersion, the surface remained unattacked at room temperature when exposed to liquid phase FNA both with and without HF.

Recent tests show that the attack on the metal upon immersion in FNA is dependent not only on the presence of an oxide coating but on the composition of the acid. With increasing NO₂ and H₂O content the tendency toward corrosion is diminished. This behavior suggests that the NO₂⁺ species may play a significant role in the initial corrosion process.¹

Chromium Steels 4130, 410, 430 and 446

Chromium steels 4130 and 410 are found to be conditionally passivated by HF in FNA. Under the

conditions of these experiments it is necessary that an unbroken oxide film on the surface of the metal be formed in moist air to obtain this conditional passivation. This condition is not as critical with alloys 430 and 446 of higher chromium content. Alloys 4130 and 410 are not recommended for use with inhibited FNA until more detailed information regarding the passivation process has been obtained.

Steel 4130 (containing 1 percent Cr) was passivated only if the film formed on the metal upon exposure to the atmosphere was left unimpaired at the time of immersion in FNA. The discussion of surface effects for steel C1020 applied equally well to steel 4130. The coated samples exposed for 16 hours at 130 degrees F to liquid phase FNA with HF were inhibited, as can be seen from Table 3, whereas those exposed to FNA without HF were seriously corroded. Recent tests show that uncoated samples were seriously corroded. Thus the oxide coating, together with HF in FNA, is necessary to ensure passivation of steel 4130. Tests of gas phase corrosion reported herein show aggravation of corrosion by HF in FNA. Recent tests have shown isolated cases of gas phase inhibition by HF, but the necessary conditions for attaining this state have not been established. The mechanism of the inhibition process is being studied further. It is possible that an atmospheric coating is necessary to slow down the initial corrosive attack so that a tenacious fluoride or oxyfluoride corrosion product can form. However, the process is so marginal that, until further investigation is carried out, this alloy is not recommended for use with FNA. The possibility of passivation is of such decided practical interest that further studies are being pursued.

Chromium steel 410 (containing 12 percent Cr) is marginally passivated by HF in FNA (see Figure 3 and Table 3), whereas steel 430 (containing 15 percent Cr) and steel 446 (containing 25 percent Cr) are more readily passivated. It appears that the coating which is of importance with the passivation of steel 4130 also is of importance with the passivation of steel 410. When the chromium content is increased to 15 and 25 percent as in steels 430 and 446, respectively, the polishing of the surface of the metal just

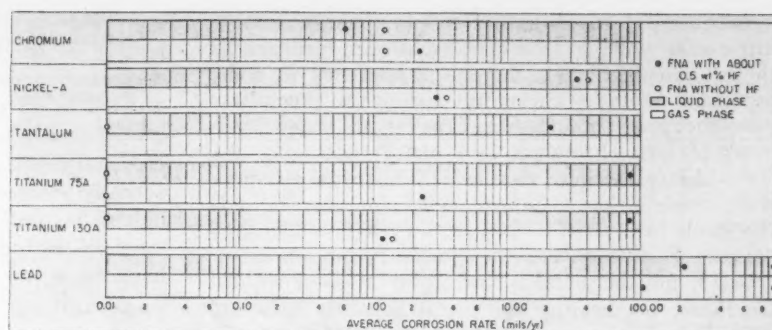


Figure 4—Summary of data on corrosion of miscellaneous alloys at 130 F by fuming nitric acid with and without HF.

TABLE 4—Summary of Data on Corrosion of Chromium-Nickel Steel Alloys at 130 F by Fuming Nitric Acid With and Without HF

Alloy	CORROSION DEPTH (mils)				AVERAGE CORROSION RATE (mils/yr.)			
	With About 0.5 Weight Percent HF		Without HF		With About 0.5 Weight Percent HF		Without HF	
	Gas	Liquid	Gas	Liquid	Gas	Liquid	Gas	Liquid
Chromium-nickel steel 302	—	0.12 ^b	—	1.89 ^e 0.96 ^d	—	3 ^b	—	46 ^e 50 ^d
Chromium-nickel steel 303	(0.016 to 0.024) ^a	(0.21 to 0.23) ^a	(0.06 to 0.2) ^f (0.9 to 1.8) ^g (0.5 to 1.1) ^h	(2.0 to 2.2) ^f (7.3 to 7.4) ^g (4.5 to 5.0) ^h	(0.15 to 0.22) ^a	(1.9 to 2.1) ^a	(3 to 10) ^f (8 to 16) ^g (9 to 22) ^h	(106 to 116) ^f (67 to 68) ^g (88 to 96) ^h
Chromium-nickel steel 304	—	0.12 ^b	—	0.74 ^e 0.48 ^d	—	3 ^b	—	18 ^e to 25 ^d
Chromium-nickel steel 321	—	0.08 ^b	—	1.15 ^e 0.58 ^d	—	2 ^b	—	28 ^e to 30 ^d
Chromium-nickel steel 347	—	0.08 ^b	—	0.66 ^e 0.44 ^d	—	2 ^b	—	16 ^e to 23 ^d
Chromium-nickel steel Armco 17-7PH	—	—	—	—	—	—	—	—
Heat treatment I	—	0.12 ^b	—	1.07 ^e	—	3 ^b	—	26 ^e to 33 ^d
Heat treatment II	—	0.25 ^b	—	3.21 ^e	—	6 ^b	—	78 ^e to 106 ^d
Chromium-nickel steel Uniloy 19-9DL	—	0.02 ^f	—	10 ^g	—	0.54 ^f	—	(244 to 248) ^g
Chromium-nickel steel Uniloy 19-9DX	—	(0.15 to 0.18) ^f 4.0 ^h	—	(0.55 to 0.58) ^g	—	(3.7 to 4.3) ^f (98 to 99) ^h	—	(13 to 14) ^g

^a Each of the seven tests refers to corrosion measurements made on samples in one vessel.

^b Test 3 continued for 15 days.

^c Test 2 continued for 15 days.

^d Test 1 continued for 7 days.

^e Test 7 continued for 40 days.

^f Test 4 continued for 15 days.

^g Test 5 continued for 15 days.

^h Test 6 continued for 19 days.

ⁱ Samples from test 5 which underwent intergranular corrosion in uninhibited FNA and were subsequently placed in inhibited FNA showed aggravated corrosion.

before immersion does not appear to impair the passivation by HF in FNA. The higher chromium content either increases the direct formation of a passivating fluoride or causes an atmospheric coating to form rapidly before immersion.

Chromium-Nickel Steels 302, 303, 304, 321, 347, Armco 17-7PH, and Uniloy 19-9DL and 19-9DX

Steels containing 18 to 19 percent chromium and 8 to 9 percent nickel are in general passivated by

hydrofluoric acid in liquid and gas phase fuming nitric acid when freshly exposed to this medium. In these austenitic steels there is a tendency in some heat treatments for chromium carbides to precipitate near the grain boundaries, causing an impoverishment of free chromium and hence increasing the corrosibility in these regions.^{2,3} This type of corrosive attack is known as intergranular corrosion. If the steels have been heated in the range 750 to 1650 degrees F, this chromium carbide formation is increased, and the metal is said to be in the sensitized condition. On heating the metal between 1920 and 2010 F, a homogeneous austenitic structure is obtained; if cooling from this temperature is rapid enough, the equilibrium formation of chromium carbides around 750 to 1650 degrees F can be prevented. Titanium and niobium (columbium), which have a greater tendency than chromium to form carbides, are added to some of these steels to reduce the tendency for chromium carbide precipitation and intergranular corrosion. A rather complete study of the corrosion by FNA of unwelded and welded 19-9DL and 19-9DX under a variety of metallurgical and physical conditions is available elsewhere.⁴

After exposure of these steels to uninhibited fuming nitric acid for several days at 130 degrees F, fairly extensive corrosion occurred. Intergranular corrosion was observed in most of the samples. When fresh samples were exposed to inhibited acid, there was good resistance against liquid and gas phase attack. These corrosion data are summarized in Figure 3 and Table 4. However, if one of these steels that had previously undergone serious corrosion was subsequently exposed to inhibited FNA, corrosion rates were higher than in uninhibited FNA. This behavior is shown by the data of Table 4 for 19-9DL. Thus it is necessary, in employing inhibited FNA with the 18-8 class of steels, to be sure that the metal has not previously undergone intergranular attack before exposure to inhibited fuming nitric acid. Aside from this restriction these steels are very suitable for use with fuming nitric acid.

Corrosion of Miscellaneous Metals by Fuming Nitric Acid

A summary of corrosion of several metals by inhibited and uninhibited FNA is given in Figure 4

and Table 5. It is evident that the passivating effect by HF in the liquid phase is slight in the case of chromium and nickel-A and is greater in the case of lead. In the gas phase, corrosion is increased with inhibited FNA. With tantalum and titanium alloys 75A and 130A, corrosive attack by inhibited FNA is actually greater than by uninhibited FNA. It should be emphasized that extreme caution⁵ should be exercised in testing titanium alloys in FNA since there have been several instances of violent explosions resulting from corrosion tests with titanium.⁶

Corrosion of Al 61S-T6 and Stainless Steel 347 by Fuming Nitric Acid with Temperature Fluctuations

In actual outdoor storage, FNA is very likely to be subjected to diurnal fluctuations of temperature. It is important to make certain that such repeated cycling of temperature does not disturb the passivation process. In a previous study¹ successive storage at 130 degrees F and 160 degrees F was found not to impair passivation, and the results of these tests with continuous fluctuations confirm the earlier results. It has been shown⁷ that peak temperatures around 160 F can be encountered in the liquid phase of a dark-colored, 55-gallon drum stored vertically and exposed to solar radiation. In the investigation reported in Reference 7 it appeared that daily temperature fluctuations could be roughly approximated by a sine-wave. Thus in the present investigation a temperature bath with a sinusoidally-varying temperature between 70 and 160 degrees F and back to 70 degrees F in a 24-hour period was used.

In Table 6 are data from corrosion tests with Al 61S-T6 and stainless steel 347 exposed for seven days to inhibited FNA in this cycling temperature. By a comparison of these data with the corresponding data at a steady temperature of 130 degrees F for Al 61S-T6 in Table 2 and for steel 347 in Table 4, it is evident that passivation occurred in the liquid phase for Al 61S-T6 and in both the liquid and the gas phase with steel 347. Although the gas phase corrosion rate of Al 61S-T6 with cycling temperature is higher than with steady temperature, a tenacious coating was apparent on the surface of the metal,

indicating that passivation had occurred. With increased storage time the rates for both phases would undoubtedly decrease. Thus, in general, it appears that with cycling temperature aluminum alloys and the 18-8 class of steels are passivated in inhibited gas and liquid phase FNA.

Corrosion of Several Metals by Nitrogen Dioxide

Samples of Al 61S-T6, steel C1020, and stainless steel 347 were exposed for 30 days to liquid and gas phase nitrogen dioxide at 130 degrees F, and the rates of corrosion observed were found to be much lower

TABLE 5—Summary of Data^a on Corrosion of Miscellaneous Alloys at 130 F by Fuming Nitric Acid With and Without HF

Alloy	CORROSION DEPTH (mils)				AVERAGE CORROSION RATE (mils/yr.)			
	With About 0.5 Weight Percent HF		Without HF		With About 0.5 Weight Percent HF		Without HF	
	Gas	Liquid	Gas	Liquid	Gas	Liquid	Gas	Liquid
Chromium . . .	0.02 ^b	0.09 ^b	0.05 ^c	0.05 ^c	0.6 ^b	2.2 ^b	1.2 ^c	1.2 ^c
Nickel-A . . .	0.12 ^b	1.4 ^b	0.14 ^c	1.7 ^c	2.9 ^b	33.7 ^b	3.5 ^c	41.0 ^c
Tantalum . . .	—	1.7	—	0 ^a	—	21 ^d	—	0 ^d
Titanium 75A . . .	0.19 ^f	6.9 ^f	0 ^e	0 ^e	2.3 ^f	84.5 ^f	0 ^e	0 ^e
Titanium 130A . . .	0.10 ^h	6.8 ^h	0.11 ⁱ	0 ⁱ	1.2 ^h	83.3 ^h	1.4 ⁱ	0 ⁱ
Lead	2.0 ^j	4.0 ^j	19 ^k	19 ^k	104 ^j	208 ^j	990 ^k	990 ^k

^a Each of the ten tests refers to corrosion measurements made on samples in one vessel.

^b Test 1 continued for 15 days.

^c Test 2 continued for 15 days.

^d Test 9 continued for 30 days.

^e Test 19 continued for 30 days.

^f Test 3 continued for 30 days.

^g Test 4 continued for 30 days.

^h Test 5 continued for 30 days.

ⁱ Test 6 continued for 30 days.

^j Test 7 continued for 7 days.

^k Test 8 continued for 7 days.

TABLE 6—Inhibition of Aluminum 61S-T6 and Stainless Steel 347 by HF in Fuming Nitric Acid with Temperature Cycling

ALLOY	CORROSION DEPTH* (mils)		AVERAGE CORROSION RATE (mils/yr.)	
	Gas	Liquid	Gas	Liquid
Al 61S-T6.....	0.049	0.016	2.53	0.84
Stainless steel 347....	0.011	0.078	0.56	4.1

* Exposure of 7 days.

than in FNA. The corrosion data obtained are shown in Table 7. It is evident even steel C1020 is fairly suitable for use with nitrogen dioxide. Stainless steel 347 was completely unattacked, the samples remaining shiny after exposure. Aluminum 61S-T6 also underwent very slight attack by this material.

In general, these metals have good resistance to this rocket oxidizer. Such behavior is not entirely unexpected since nitrogen dioxide liquid is quite nonpolar in nature compared with fuming nitric acid.

Conclusions

The results of the corrosion tests show that in general, aluminum alloys were inhibited against both liquid and gas phase corrosion by the presence of HF in FNA. These alloys are recommended for use with inhibited FNA and are fairly stable with uninhibited FNA. The 18-8 chromium-nickel class of steels is passivated in both phases if freshly exposed to FNA containing HF, and these materials are suitable for use with inhibited and fairly stable with uninhibited FNA. The passivating coating on aluminum and 18-8 steel alloys is stable only in FNA in the presence of HF. If there are areas of the 18-8 steels where previous extensive corrosive attack has occurred, HF in FNA aggravates the corrosive attack at these anodic areas.

In steels containing less than 15 percent chromium and having no nickel as an alloying element (steels 4130 and 410), inhibition by HF in the liquid phase was assured only if the surface of the metal upon exposure to FNA contained an oxidation film from moist air. Gas phase corrosion was usually increased by HF in FNA in the case of steel 4130. At present these alloys are not recommended for use with either inhibited or uninhibited FNA. The sensitivity of these materials to this conditional passivation decreased with an increase in Cr content found in steels 430 and 446. These alloys are recommended for use with inhibited FNA.

Liquid phase corrosion of carbon steel was inhibited by HF in FNA if an oxide film was present. However, because of the critical conditions required for passivation, this material is not considered suitable for either inhibited or uninhibited FNA. Liquid phase corrosion of tantalum and titanium alloys was increased by HF in FNA. Thus tantalum is recommended for uninhibited but not for inhibited FNA. Titanium alloys are not recommended for use with either type of FNA until the danger of explosions is eliminated. Liquid phase corrosion rates of chromium, nickel-A, and lead were slightly improved by the presence of HF in FNA, and these materials are considered suitable for use with inhibited FNA (although gas phase corrosion of chromium is slightly increased).

TABLE 7—Summary of Data on Corrosion of Several Metals at 130 F by Nitrogen Dioxide

ALLOY	CORROSION DEPTH* (mils)		AVERAGE CORROSION RATE (mils/yr.)	
	Gas	Liquid	Gas	Liquid
Al 61S-T6.....	0.020 0.024	0.023 0.029	0.25 0.29	0.28 0.36
Steel C1020.....	0.24 0.27	0.039 0.052	2.94 3.26	0.48 0.63
Stainless steel 347....	0	0	0	0

* Exposure of 30 days.

Storage for prolonged periods with sinusoidal temperature fluctuations between 70 and 160 degrees F in 24 hours as might occur in field storage did not impair inhibition by HF of gas and liquid phase corrosion of the aluminum and stainless-steel alloys tested; thus these alloys appear to be passivated generally under these conditions. Aluminum 61S-T6 and stainless steel 347 showed good resistance to corrosion by gas and liquid-phase NO_2 . Carbon steel C1020 showed slight attack in this medium.

Although in the case of aluminum alloys the inhibiting effect of hydrofluoric acid in FNA appears to be due to the formation of a tenacious coating of an insoluble aluminum-fluorine compound on the surface of the metal, further investigation of the mechanism of passivation with steel alloys is continuing. There remains to be studied in detail for all metals the effect of the ratio of surface area of metal to volume of acid on the passivation process. The nature of the mechanism of the oxidation coating on the process of passivation with the chromium steels is being further studied. A fundamental investigation of the actual kinetics of corrosion (e.g., the species which in FNA is primarily responsible for the corrosive attack) is being pursued. The effectiveness of passivation in flowing systems is also of interest. It is hoped that such further studies will be of applied value in extending the conditions for use of hydrofluoric acid as an inhibitor of corrosion by the important rocket oxidizer, FNA.

Acknowledgment

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Interpretation of Tubing Caliper Surveys*

By VICTOR W. MAXWELL and BEN D. PARK

Introduction

SINCE THE initial use of the caliper instrument for the detection of corrosive action by well fluids on tubing under actual well conditions, the number of tubing strings being surveyed each year in the Gulf Coast Division of the authors' company has steadily increased. To date, the information obtained from these caliper surveys has been used in a limited way only; namely, (1) as criteria for determining the footage of tubing which needed replacing before a workover was performed, and (2) as a primary means of detecting corrosion in a well or a field.¹ The latter usage has been in conjunction with iron content analyses of produced waters, coupon exposures, and equipment failures.

The corrosion status of a well (i.e., slight, medium, or severe), and the treatment efficiency of a corrosion inhibitor have been based strictly on the experience and opinions of the persons interpreting the surveys rather than on any form of a constant numerical limit.

This additional tabulation of the tubing caliper survey report has been designed to achieve a clearer picture of the condition of the tubing in a producing gas or oil well, and to establish some basis for determining the treatment efficiency of corrosion inhibitors.

Basis for Establishing Limits

The extreme value theory, used by G. G. Eldredge,² was considered as a possible means of interpreting tubing caliper reports studied by this laboratory. It was decided that a different method might be developed to expedite the handling of the three to four hundred surveys made annually for the Gulf Coast Division of the authors' company. The proposed method differs from the Extreme Value Theory in that (1) it employs percent penetration rather than pit depth, and (2) it defines corrosion status and assesses treatment efficiency rather than predicting complete penetration or ultimate tubing failure.

The method used in the proposed interpretation is exclusively empirical, and the limitations imposed are based on field experience. For practical purposes, the maximum penetration within a joint determines its status. If the tubing string is considered as a whole and the ranges of penetration made broad enough, pitting frequency should be accounted for by the number of joints having a maximum penetration within a given range.

It was considered expedient to use the tabulated penetrations recorded in tubing caliper reports with-



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Abstract

An arithmetical interpretation of tabulated data is derived in an effort to obtain the maximum utilization of tubing caliper surveys. Analysis of consecutive surveys allows the engineer to determine the corrosion status of a string of oil well or gas well tubing and to assess a treatment efficiency. Limits assigned were based on field experience of grading tubing. Limits are therefore not inflexible and may be changed to meet specifications of any company or can be standardized throughout the industry as more information is compiled. The proposed method offers a simple yardstick to the corrosion engineer which previously was not available in the area of tubing caliper surveys.

2.1.2

out differentiating between ringworm type corrosion and general pitting. Ringworm type corrosion can be assumed because of its location at the end of a joint. There is however no proof of its existence except by visual inspection since underfills, or mill wrinkles in the upset zone, can resemble corrosion on a caliper survey.

There are no universally established ranges of penetration which govern corrosion status and treatment efficiency. Several different ranges were studied from which three ranges of percent penetration were found to be sufficient to reflect conditions of slight, medium, and severe corrosion and to aid in the assessment of treatment efficiency. It was decided

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that pits of less than 15 percent would not be regarded as corrosion for several reasons. Mill deviations, mill scale, and instrument error are often represented as pits of less than 15 percent penetration.

Range 1 was set up to include penetrations of 15 percent through 25 percent. The upper limit of this range was fixed to include 25 percent penetration, a value usually considered as slight corrosion.

Range 2 includes penetrations greater than 25 percent through and including 50 percent. Since Range 2 was set up to include pits which are indicative of medium corrosion, the top limit of this range had to be the average figure beyond which pits were labeled "severe." The value of 50 percent penetration was chosen as a dividing line between "medium" and "severe." Therefore, Range 3 includes all pits greater than 50 percent.

The assignment of limits to corrosion status is based on a series of numerical values. The values are the percent of the total number of joints which appear within a respective range. The names "slight," "medium," and "severe" are carried over from the terminology of the company's tubing caliper reports.

For the purpose of this interpretation, slight corrosion is the condition wherein less than 5 percent of the total number of joints appear in Ranges 2 and 3 combined. When the above value is equal to or greater than 5 percent, the status is medium. Severe corrosion is the condition that 5 percent or more of the total number of joints surveyed appear in Range 3.

The treatment efficiency grading system is based essentially on a set of limits for an annual increase of the number of joints within the three ranges of penetration. The lower limit of annual increase chosen to indicate no protection was 4 percent in Ranges 2 and 3 collectively, and 8 percent in Range 1. Since limits have been established for a grade of "no protection," several possible combinations of annual increases in each of the three ranges were tried in order to arrive at numerical limits for four additional grades. These grades were designated as "excellent," "good," "fair," and "poor." Since increases in Range 1 were considered separately from the combined increases of Ranges 2 and 3, there were a number of possible combinations of limits. A mathematical expression of these limits by which a grade might be determined proved to be impracticable. Therefore, an area graph was developed. An explanation of this graph is found under the code index section of this paper.

The division of the string into three sections is designed to provide the information that the corrosive action may be highly localized. This breakdown of pitting distribution will call attention to the fact that overall protection may appear to be good, but that a given area may continue to corrode rapidly. The recourse is then to make a separate study of the actual caliper charts instead of the reports of percent penetration. The results of such a study are then recorded on the reverse side or "Remarks" section of the interpretation card. Localized pitting is the

exception to the rule rather than the normal case; therefore, no provision was made for the case of isolated corrosive zones when the limits used herein were developed.

The assignment of a corrosion status and treatment efficiency is based on the total number of joints surveyed unless the situation warrants separate treatment as mentioned above. Corrosive attack in an untreated oil or gas well follows no set pattern; therefore, these limits were established to include the entire string.

The limits assigned herein are flexible so that this method may be used as an outline by any company which desires to change them to meet their specifications. These assigned limits were based on studies of wells of approximately 7000 feet in depth and deeper. When this method of interpretation is applied to shallow wells, the numerical values for corrosion status and treatment efficiency become critical. In other words, as the total number of joints surveyed decreases, the influence of one pit increases. The few shallow wells that are surveyed periodically in the Gulf Coast Division do not warrant the establishment of a different set of limits for corrosion status and treatment efficiency.

Code Indexing of Data Cards

The total number of joints calipered and the joint-wise listing of percent penetration found in a tubing caliper report may be tabulated as shown in Table 1. This is the source of data for the outlined method of interpretation.

A 5 inch x 8 inch card was chosen as the most effective form for recording and filing the interpretations. In order to simplify the headings and to explain the card's function, a code index was developed. (See Table 2.)

The ranges have already been referred to as 1, 2 and 3.

1. Fifteen percent through and including 25 percent penetrations.
2. Penetrations greater than 25 percent and including 50 percent.
3. Penetrations in excess of 50 percent of wall thickness.

Under each range there appear three lower case letters, a, b and c:

- a. The number of joints having a maximum penetration within a respective range.
- b. The percent of the total number of joints surveyed that have a maximum penetration within a respective range.
- c. The increase in "b" from the prior run, expressed as the percent of the total number of joints surveyed.

The tubing is divided into thirds (U, M and L) to indicate zones of corrosion:

U: Upper third.

M: Middle third.

L: Lower third.

T: Total string—basis for assigning status and treatment efficiency.

The corrosion status is coded as follows:

1: Slight (2b + 3b is less than 5).

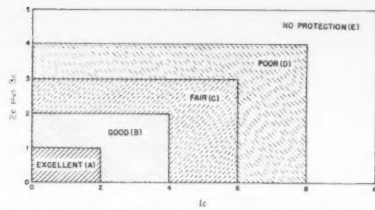


Figure 1—Treating efficiency grading graph.

2: Medium (2b + 3b is equal to or greater than 5).

3: Severe (3b is equal to or greater than 5).

Treatment efficiency is derived from the area graph of 2c + 3c versus 1c. Points falling within a shaded area are assigned the grade for that area. A

TABLE 1—Jointwise Listing From Tubing Caliper Reports

Run No.	Joint No.	% Penet.	Joint No.	% Penet.	Joint No.	% Penet.
1*	27	15	162	30	281	15
1	32	30	175	15		
1	46	25	176	20		
1	59	30	179	20		
1	60	20	181	15		
1	86	15	185	15		
1	103	15	207	30		
1	109	30	219	25		
1	111	30	230	15		
1	115	25	268	15		
2**	27	20	162	35	207	55
2	32	35	175	20	208	15
2	46	25	176	30	219	35
2	59	30	179	30	220	15
2	60	30	180	15	230	30
2	86	15	181	20	233	15
2	103	20	182	15	242	20
2	109	55	183	15	268	25
2	111	55	184	15	281	20
2	115	35	185	20		

* 300 Joints Calipered.

** 300 Joints Calipered.

TABLE 2—Tubing Caliper Data

Field	JUPITER	Lease	JOHN DOE	Well No.	1	Treated: X	Untreated:						
Date	Run No.	No. Joints Surveyed	1			2			3			Corr. Status	Treatment Efficiency
			a	b	c	a	b	c	a	b	c		
	1	U 100	4	1.33		2	0.67		0				
		M 100	7	2.34		3	1.00		0				
		L 100	4	1.33		1	0.33		0				
		T 300	15	5.00	—	6	2.00	—	0	0	—	(1)	
	2	U 100	3	1.00		3	1.00		0	0			
		M 100	8	2.67		4	1.33		2	0.67			
		L 100	6	2.00		2	0.67		1	0.33			
		T 300	17	5.67	0.67	9	3.00	1.00	3	1.00	1.00	(1)	C
		U											
		M											
		L											
		T											
		U											
		M											
		L											
		T											
		U											
		M											
		L											
		T											

point falling on a boundary line is assigned the inferior grade (see Figure 1). The grades are:

A: Excellent

B: Good

C: Fair

D: Poor

E: No Protection

Sample Calculations

All the calculations needed for this type of tubing caliper interpretation are relatively simple. A method of calculation with examples is given below. The values found on the sample data card, Table 2, are used in the following steps. The total number of joints calipered and the number of joints penetrated were assumed for this example and tabulated in Table 1.

Step 1: The total number of joints calipered is divided into thirds as nearly as possible, avoiding any fraction of joints. For example, Table 2, Run 2 shows a total of 300 joints calipered, or 100 joints per third (1-100, 101-200, 201-300). If the number of joints had been 302, a possible division would be upper—100, middle—101, and lower third—101 joints (1-100, 101-201, 202-302).

Step 2: A count of the number of joints with a maximum percent penetration, included in the limits of the respective Ranges 1, 2 and 3, is made from the jointwise listing given in Table 1. These values are entered under the lower case letter "a" opposite the thirds of the string indicated by U, M, L, and the total T. For example, in Table 2, Run 2, Range 1, the values under "a" are U—3 (joints 27, 46, and 86), M—8, L—6, and T—17.

Step 3: Calculations for the value entered under the lower case letter "b" of each respective range are made by using the formula

$$\frac{a}{T} \times 100 = b$$

(a, b, and T are defined under the Code Indexing of Data Cards.) This calculation is made for each third and the value is entered appropriately on the data card as stated above. For example, Table 2, Range 1, Upper: a = 3 and T = 300

$$b = \frac{3}{300} \times 100 = 1.00$$

The total value of "b" is a simple addition of the values of "b" for each third (Ub + Mb + Lb = Tb). The reason for the addition is that in rounding off the values of "b," there is sometimes a discrepancy between the sum of the values for the thirds and the quotient of a/T × 100 for the total number of joints within a respective range.

Step 4: A value for the lower case letter "c" under the respective ranges can only be calculated after two consecutive caliper surveys have been made since it is the difference between the total value of "b" for the two runs. For example, in Table 2, Range 2, the total value of "b" from Run 2 is 3.00 and from Run 1 is 2.00; therefore, the difference "c" is 1.00.

Step 5: Calculations for the corrosion status are explained in the Code Indexing of Data Cards. A simple addition of the total values of "b" for Ranges 2 and 3 is all that is required. For example, the values of 2bT and 3bT are 3.00 and 1.00 respectively (Table 2, Run 2). Since 3bT is less than 5, the status cannot be severe. The total value of 2bT and 3bT, 4.00, is also less than 5, so the status cannot be medium. Therefore, the status is slight, and a "(1)" is entered appropriately on the data card.

Step 6: Calculations for assigning the treatment efficiency grade are equally as simple. The values of 1c and $2c + 3c$ are plotted on the area graph (Figure 1) to obtain the grade. For example, Table 2, Run 2, the values are $1c = 0.67$, $2c = 1.00$, and $3c = 1.00$; $2c + 3c = 2.00$. The grade obtained is "C" (or "Fair"), which is entered on the data card under the heading Treatment Efficiency.

Discussion of Results

Approximately 260 tubing caliper surveys on 111 wells were studied in the Gulf Coast region. The latter figure includes 61 oil and 50 gas-condensate wells. The bases for choosing these wells were that there had been more than one survey made on them since initiating inhibitor treatment and there had been no alterations made to the tubing strings between surveys. In addition to these studies, approximately 180 wells have had initial surveys tabulated.

These wells are representative of the corrosive conditions which exist in the area studied. They exhibited the full range of limits assigned to corrosion status and treatment efficiency (see Table 3). There were 58 wells which were classified as having slight corrosion; 43 medium; 10 severe. The reason that only 10 wells were classified in the latter status may be substantiated by the fact that most tubing strings are replaced when they become severely cor-

roded. In cases where well conditions have not warranted replacement of the tubing, many severely corroded strings have remained in service for two or more years when an inhibitor treatment program was initiated early enough. Far better results have been obtained when corrosion inhibitor treatment was initiated in the early corrosive histories of wells than when treatment was delayed until corrosion became medium or severe.

The detergent action of an inhibitor may remove scale and corrosion products which had misrepresented the degree of corrosive attack as determined by tubing caliper surveys. In most cases studied in this laboratory, corrosion is found to be more severe than was anticipated after the scale and corrosion products are removed. The second caliper survey following the initiation of treatment with an effective inhibitor will probably show that pitting frequency and depth have increased very little.

Table 4 includes data from three Texas Gulf Coast wells to illustrate probable detergent action and subsequent protection by an inhibitor. There have been some instances in which the frequency and severity of pitting has apparently decreased. There are three conclusions which may be drawn for these instances. First, the caliper instrument may fail to track its previous run; second, the apparent corrosion represented on the prior caliper survey may have been a hard, pitted scale which has since been removed; third, the caliper instrument may have been less sensitive on the later run.

In a separate study of gas-condensate wells made in a Louisiana Gulf Coast field in early 1956, the corrosive histories of 32 wells were compiled (see Table 5). All of the wells were found to be corroded to some extent upon the initial survey. Of these wells, five were so severely corroded as to require immediate replacement of the tubing. Three of the wells were classified as having medium corrosion. Inhibitor treatment was initiated shortly after discovery of the corrosion.

One of the wells had such a high tubing pressure (6900 psig) that the tubing was pulled and replaced with a stronger grade of internally plastic coated tubing. The maximum penetration was 40 percent in one joint, so that most of the string was salvaged as usable tubing. Another of these strings is still in service with little increase in corrosion. The third string is in a shut-in well. Treatment was stopped when it was shut in, but corrosion in the mid-section of the tubing (probably fluid level) has increased severely. Of the 24 remaining strings originally classified "slight," 12 are still in the same status. Six more have increased to medium, one has increased to severe and remained in service, and five have had tubing replaced. All wells received treatment within several months to one year after corrosion was detected.

The safest conclusion to draw in studying the corrosivity of a well in the Gulf Coast area is that corrosion is likely to occur, and the se-

TABLE 3—Corrosion Status and Treatment Efficiency

Corrosion Status	TREATMENT EFFICIENCY					Total
	Excellent (A)	Good (B)	Fair (C)	Poor (D)	No Protection (E)	
Slight.....	41	8	4	4	1	58
Medium.....	4	5	7	7	20	43
Severe.....	2	1	0	1	6	10
Total....	47	14	11	12	27	111

TABLE 4—Detergent Action of a Corrosion Inhibitor

Well No.	FIRST SURVEY FOLLOWING INITIATING TREATMENT				SECOND SURVEY FOLLOWING INITIATING TREATMENT			
	1c	2c + 3c	Status	Eff.	1c	2c + 3c	Status	Eff.
1.....	7.05	10.55	(3)	E	0.99	0.98	(3)	A
2.....	6.8	3.24	(1)	D	2.51	0.06	(1)	B
3.....	2.61	7.34	(2)	E	0.74	0	(2)	A

verity of corrosion will vary with the rate of production. Therefore, it seems wise to consider corrosion inhibitor treatment before the tubing string has become more than slightly corroded, as detected from tubing caliper surveys.

The proposed method of interpreting tubing caliper surveys should provide the corrosion engineer an additional means of assessing corrosion status and treatment efficiency. This additional utilization of information that is available from tubing caliper surveys should add to the value of the instrument in studying corrosion in oil and gas wells.

References

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2. G. G. Eldredge. Analysis of Corrosion Pitting by Extreme-Value Statistics and Its Application to Oil Well Tubing Caliper Surveys. *Corrosion*, 13, No. 1, 51t-60t (1957) January.

DISCUSSIONS

Question by M. J. Olive, Arkansas Fuel Oil Corp., Shreveport, La.:

Does your company calculate the bursting value or collapse value of tubing from caliper surveys? If it does, what is the formula?

Reply by B. D. Park:

No, we do not calculate the bursting value or collapse value of tubing from caliper survey. The area of a pit, as detected by a tubing caliper, cannot be determined, especially for ringworm type corrosion. We feel that more information than pit depth would be required to make such a calculation. However, we do consider burst and collapse strength in recommending the replacement of corroded tubing.

Question by C. C. Nathan, Bellaire, Texas:

What have you observed about the relation of pit depth to pit diameter? Does the ratio hold constant

TABLE 5—Gas-Condensate Well Study*

Total number of wells studied.....	32
Wells found to be corrosive.....	32
Wells requiring immediate maintenance	
workover when corrosion detected.....	5
Wells with "medium" corrosion when detected.....	3
Wells, above, which have had tubing replaced.....	1
Wells, above, which have slightly increased	
corrosion since treatment.....	1
Wells, above, which have increased to	
"severe" since treatment (now shut in).....	1
Wells with "slight" corrosion when detected.....	24
Wells, above, which have had tubing replaced	
since treatment initiated.....	5
Wells, above, which have exhibited slight	
increase in corrosion since treatment.....	2
Wells, above, which have increased to "medium"	
corrosion since treatment.....	6
Wells, above, which have increased to "severe"	
corrosion since treatment.....	1

* Based on corrosion status and tubing string replacements from tubing caliper interpretations and maintenance workovers, respectively.

with time for a particular untreated well? If so, then it would not be expected that pit depth would increase with time, but rather with the cube root of the time. That is, for caliper surveys repeated at equal time intervals, there would be an apparent reduction in rate of pit depth increase. This would mislead one into thinking that an inhibitor program was being effective.

Reply by B. D. Park:

We have made no studies of the relationship between pit depth and pit diameter. Most of the studies of that nature would have to be on sectioned pieces of tubular goods. The few pieces of tubular goods made available for our complete inspection have not provided enough information for us to make a definite conclusion.

We do not think that corrosion proceeds at a linear rate. However, the broad ranges of penetration depth that we have used in our interpretations have enabled us to make fairly reliable estimates of inhibitor treatment efficiency, based on two to three years of caliper surveys.

Any discussions of this article not published above
will appear in the June, 1958 issue



DISCUSSIONS

The Effect of Dissolved Oxygen on the Corrosion of Steel and on Current Required for Cathodic Protection by E. Schaschl and G. A. Marsh. *Corrosion*, Vol. 13, No. 4, 243t-251t, (1957) April.

Discussion by Ulick Evans, Cambridge, England:

The extremely interesting paper by Schaschl and Marsh has led to some friendly correspondence about the relationship between laboratory results and field behavior. Mr. Marsh has kindly suggested that readers of *Corrosion* might care to know my views. I should rather welcome an opportunity to make them known, since several American friends have told me that the plan of using the break in the I-V curve of a pipe line as a sign of adequate protective current arose partly out of a paper published 26 years ago from my laboratory.¹ That paper described the first part of a pure-science research which later established the fact that the electric current flowing on iron partly immersed in chloride solution is equivalent, in the sense of Faraday's law, to the measured corrosion-rate.² The object of the research was to study the scientific mechanism of corrosion and not to develop a method of protection for use in the field.

In the paper mentioned, published with Bannister and Britton,¹ it was shown that when a cathodic current is applied from an external anode to non-ferrous metal corroding in stirred potassium chloride solution containing oxygen, the potential remains constant over a considerable range of applied current. The interpretation offered was that the area undergoing corrosion extends until the cathodic current density on the uncorroding portion becomes sufficient to confer protection, probably by maintaining the appropriate concentration of inhibitive potassium hydroxide next to the metal. When once a protective current density has been reached, the attack can extend no further. Since the cathodic current density depends partly on the local cathodic reaction (reduction of oxygen) and partly on the current supplied from the external anode, it follows that, as the strength of applied current is altered, the ratio of anodic and cathodic areas may alter also, but that the effective current density in the steady state should remain independent of the applied current; consequently, the potential should also be independent of the applied current—as was found to be the case.

This argument assumes that the corrosion product does not interfere with the local current. In the case of iron, ferrous hydroxide absorbs oxygen with avidity and this must affect the local corrosion reaction, so that the situation is here complicated. The I-V curves for iron do show a break, but the position

may be poorly defined, and the form of the curves varies with time. Only non-ferrous metals show well-developed horizontal limbs on the I-V curves.

It would seem that the method of using the end of the horizontal limb to decide the current strength at which protection becomes complete in the field, would require modification before it could be applied with any confidence to a steel pipe. Even for a non-ferrous pipe, the end of the horizontal limb would not give the engineer what he needs. At best, it would show the current at which a "typical" point on the pipe surface receives protection; but the engineer requires the current which will stop corrosion at those points on the pipe which are the least favorably situated for protection—either owing to their remoteness from the external anode, or through some local characteristic of the soil (e.g. a salt-pocket). The method would at least need modification and development to provide this.

While writing on the relation between laboratory and field results, it may be useful to recall what I have stated elsewhere in connection with boiler problems³—namely that there are two distinct factors which may cause laboratory observations to be misleading. One arises from dimensional considerations and the other from statistical considerations.

Some years ago, Hoar and Agar,⁴ considering the distribution current in an electrolytic cell, reached the conclusion that if all linear dimensions of the cell are increased N times, the distribution of current and potential will be altered unless the specific conductivity of the liquid is also increased by a factor of N . If this increase can be achieved without altering other pertinent properties (such as oxygen solubility), the small-scale model should provide accurate information of large-scale results. Hoar and Agar pointed out that polarization is generally the most important current-restricting factor in small-scale cells and resistance in large-scale cells. The same point has been brought out by Waber, who has published an important series of mathematical papers dealing with dimensional aspects of corrosion and has recently provided a convenient summary of his views.⁵

The statistical cause of discrepancy arises in many cases of localized corrosion—for instance where a saline liquid has been treated with inhibitor in an amount insufficient to stop attack at the most susceptible points. The greater the addition of inhibitor, the smaller becomes the number of "virtual" starting points per unit area (i.e. the points where attack would start if there were no complications such as cathodic protection afforded by neighboring points of corrosion). Supposing that the inhibitor addition has been sufficient to reduce the virtual starting points to 1 per square foot. On a laboratory

specimen measuring 1 square inch, the chance of a starting point becomes 1 in 144 and even if the experiment is repeated two or three times, the results will almost certainly indicate that the inhibitor addition has been sufficient to prevent attack. Now supposing liquid containing this same amount of inhibitor is used in a technical plant of area 1 square yard, the "expected number" of virtual starting points is 9 and the chance of actually obtaining no actual starting points when the expected number of virtual starting points is 9, can be shown, by Poisson's Theorem to be only 1.2341×10^{-4} . Thus, whereas the laboratory experiment has suggested that the liquid is "safe," industrial experience will almost certainly show it to produce corrosion.

These arguments should not lead us to abandon laboratory testing. There are problems where laboratory measurements—suitably planned so as to avoid contravention of basic statistical or dimensional principles—could give reliable predictions of field behavior. But an attempt to apply a method designed for a pure-science purpose without suitable modification to an industrial problem is in certain cases liable to lead to disappointment and perhaps to disaster, although the information provided by the pure-science research, properly understood, should generally be helpful in devising a reliable technical method.

References

1. U. R. Evans, L. C. Bannister and S. C. Britton. *Proc. Roy. Soc. (A)* **131**, 355 (1931) esp. p. 368.
2. U. R. Evans and T. P. Hoar. *Proc. Roy. Soc. (A)* **137**, 343 (1932) esp. p. 364.
3. U. R. Evans. *Trans. Inst. Marine Eng.* **69**, 144 (1957).
4. T. P. Hoar and J. N. Agar. *Discussions of the Faraday Society*, **1**, 158 (1947).
5. J. T. Waber. *Corrosion*, **13**, 95t (1957).

Testing Methods and Corrosion Control Measures for Buried Telephone Cable by Daniel R. Werner. *Corrosion*, Vol. 13, No. 5, 338t-344t (1957) May.

Question by B. Husock, Harco Corp., Cleveland:

The methods outlined in this paper appear to be primarily concerned with the location of "hot spots" resulting from "long line" activity. It has been said by many pipelines that most corrosion on bare pipelines results from "local action." Would this not also be true of corrosion on underground cable?

Reply by Daniel R. Werner:

In telephone parlance, underground cable is cable in conduit and buried cable is cable placed directly in the earth. Toll cables (with or without a steel tape overlay over the lead sheath placed directly in the earth, always have some kind of a wrapping and are never bare. A jute wrapping has been used in the past and is presently being used. The jute is a very poor insulator but nevertheless appears to have sufficient resistance to lessen corrosion currents due to local action and this seems to be borne out by past history since very few failures of the lead sheath have been experienced on buried cables.

From this it should not be inferred that corrosion

is not occurring, for the steel tapes surrounding the lead are corroding, as we have received reports of such in connection with road changes, cable lowering jobs and repair work. In many cases the steel has completely disappeared but the lead sheath has not been affected. It is considered impracticable to prevent the steel from corroding under jute coverings due to the cost of providing —.85 volt protective potential. The lead sheath requires a smaller protective potential and effort is being directed toward making the cable sufficiently negative overall to protect the lead sheath together with locating and eliminating "hot spots."

Question by E. F. Costanzo, Manufacturers Light and Heat Co., Pittsburgh:

Why weren't coordinated equalization ties made instead of tape coating in the solution of your problem presented in Figure 7? It seems that an interference problem caused by the pipeline rectifier could be equalized by cooperative test to the mutual satisfaction of all. The economics of coating certainly has to be considered. The possibility of holiday in the coating with the deterioration in time will make a joint equalization tie a necessity anyway.

Reply by Daniel R. Werner:

A equalizing bond was tried at the points of crossing with the 22-inch and 24-inch pipeline, but these did not prove adequate to provide a reversal in the current flowing on the cables at Marker 148 away from the crossing in the pipelines. A full size 2½-inch diameter buried jute covered telephone cable may be considered to be the same as a very poorly coated steel pipe about 1¼ inches inside diameter. The usual size buried toll cable is somewhat smaller and would be about the equivalent of a one-inch size pipe in conductivity.

The jute used on the cable is a very poor insulator and it is readily susceptible to electro-osmosis with any increase in cable-to-soil potential. Water is driven through the jute as a result of electro-osmosis and the pH of the water is increased, making it alkaline. With certain types of cables a steel tape is wound over the lead and as is well known, lead will corrode when lead and steel are connected together and immersed in an alkaline solution. Consequently, the decision was made to tapecoat the cables to reduce the current pickup and drainage requirements at the pipeline crossings.

Question by W. S. Woodward, New York Telephone Co., New York:

What effect would a parallel structure—i.e., pipe line with cathodic protection have on your survey?

Reply by Daniel R. Werner:

Current in the earth from cathodic protection systems on paralleling structures may be picked up and discharged by the cable. In current pickup areas the cable-to-soil potentials would test more negative, whereas in current discharge areas the cable-to-soil potentials would, under uniform soil conditions, test less negative or even positive to a copper-copper

sulphate half cell. If by chance the current discharge area is also a hot spot area, where in the absence of stray current from the cathodic protection system the cable-to-soil potential would test more negative, then the cable-to-soil potentials may not be indicative of what is occurring and side gradient tests must be relied upon to indicate current loss areas.

Some Observations on Cathodic Protection Criteria—A Contribution to the Work of NACE Technical Unit Committee T-2C on Minimum Current Requirements, by L. P. Sudrabin and F. W. Ringer. *Corrosion*, Vol. 13, No. 5, 351t-357t (1957) May.

Comments by Joe F. Tatum, Willmut Gas Co., Hattiesburg, Miss.:

In the evaluation of the current potential break method I do not believe all necessary factors were considered in that steel can approach a zinc solution potential in some soils, but I do not believe the soil used in this experiment was representative of those conditions. The potential break as indicated could have been the protection point for the steel even though the zinc anodes still showed considerable current flow. I would also like to point out that another factor to be considered is the insertion of the meter resistance of the ammeter between the synthetic anode and cathode. To obtain a true condition this resistance would have to approach those commonly found in practice.

In application of cathodic protection to bare type no one criteria will give 100 percent results. The engineer must rely on polarization tests, current potential curves, two-cell survey investigations, remote electrode, line voltage drops and any other tests deemed necessary by the character of the soil involved. A correlation and interpretation of this criteria will lead the engineer to a reasonable conclusion of the completeness of protection and the economic current required.

Comments by B. Husock, Harco Corp., Cleveland:

In the February, 1956, issue of *Corrosion*, a paper entitled "A Study of Protective Criteria on a Pipe Section in a Uniform Environment," by L. P. Sudrabin, was published. The information in that paper was expanded in a paper entitled "Some Observations on Cathodic Protection Criteria," presented by the same author at the Annual Conference in St. Louis.

It should be pointed out that the use of small zinc coupons to simulate the behavior of an anodic area on a pipeline does not simulate the behavior of corroding iron in most environments. Thus, the coupling of a small zinc plate to a large iron area, will more than likely result in a corrosion system which is under anodic control. The authors in the paper presented in St. Louis state that the corrosion of iron in well-aerated high resistivity soils is probably under mixed control, while other investigators have shown that the corrosion of iron in most environments is more nearly described as being under cath-

odic control. Therefore, although the geometry of the systems set up by the authors is similar to that of an anodic area on an iron pipe surface, it is difficult to consider the results as useful in determining the corrosion characteristics of steel pipe in view of the fact that the corrosion mechanisms are dissimilar.

The authors of "Some Observations on Cathodic Protection Criteria" state that "the potential difference between the zinc anodes and the steel pipe is not an unusual representation of the potentials found in a corroding system." The justification for this statement is derived from the concept that open circuit potentials between iron behaving as an anode and iron oxide can exceed one volt. It would appear that the equating of a zinc-iron corrosion mechanism with the corrosion of iron requires greater justification than similarity between the open circuit potentials of the systems.

Comments by W. J. Schwerdtfeger, National Bureau of Standards, Washington, D. C.:

It is believed that Sudrabin and Ringer have taken the correct approach in striving for criteria which result in complete rather than adequate protection. Their work shows that all criteria must be compatible with the Mears and Brown theory¹ based on the open-circuit potential of the most anodic element. Their experimental data reveal that small anodic areas surrounded by relatively large cathodic areas are not only difficult to detect but also to suppress, more protective current being initially required as the area ratio increases.

The writer ran a somewhat similar experiment, but on a relatively much smaller scale, using for a cathode a 0.5-inch diameter steel rod shaped in the form of a ring (area 48 sq. in.) and containing an insulated zinc plug having an exposed area 1/1000 that of the steel. The couple was exposed to local soil contained in a box, the soil having been treated so as to have a resistivity around 1000 ohm-cm. A zinc cylinder symmetrically arranged with respect to the couple was used to supply current to the couple from an external power source. While in the process of obtaining a cathodic polarization curve on the couple, involving a time period of about 40 minutes, it was observed that the applied current was in the order of 225 times the magnitude of the galvanic current before reducing it to zero at which time the potential of the couple was the same as the open-circuit potential of the zinc plug. The break (change-in-slope) in the polarization curve occurred at a value of applied current which was consistent with the local action current on the steel ring, the applied current being only about 1/5 that required to reduce the galvanic (Zn-Fe) current to zero even though the local action current was 40 times the order of magnitude of the Zn-Fe current. The change-in-slope in the polarization curve indicated the current required to prevent local action and when this current was maintained the current leaving the zinc plug was also gradually reduced by polarization.

Consider now the experimental pipeline described by Sudrabin and Ringer. When plotting cathode potential against the logarithm of the applied current

(Figures 10 and 11), the current required for cathodic protection is considered as occurring at the intersection of the line of maximum slope and the best straight line drawn through points of lesser current. In Figures 10 and 11, this intersection occurs somewhere between 130 and 160 ma. The galvanic current from the zinc anodes, 1 and 2, totals 2.9 ma (Table 2). In order to evaluate the significance of the break in the polarization curves, the 2.9 ma ought to be compared with the total local action (corrosion current) occurring on the 40 feet of iron pipe. In order to get an approximate idea of the magnitude of the local action current, known weight losses on iron in soils of similar resistivity might be converted to equivalent corrosion currents by applying Faraday's law. The authors reported soil resistivities varying between 16, 100 and 37,000 ohm-cm at the depth to which the pipe was buried. Accordingly, data pertaining to 5 soils, ranging in resistivity from 11,000 to 38,600 ohm-cm, were selected from the National Bureau of Standards Circular 579 (C450 revised).² The weight losses (Table 13) which were measured on four varieties of 3-inch wrought ferrous pipe specimens after the first two-year exposure period were averaged for soil numbers 3, 11, 31, 38 and 42, comprising a total of 40 specimens.

The average metal loss for the two-year exposure period was 1.2 oz/ft.² corresponding to a Faraday equivalent of about 1.9 ma-ft.² For 40 ft. of 6-inch iron pipe, this would represent (on a linear basis) a local action current of about 130 ma. Thus, as Figures 10 and 11 show, the current (1.9 ma) flowing from the zinc anodes, 1 and 2, would not be expected to noticeably influence the values of current at which the breaks occur.

If it is assumed that the local action current as calculated is reasonable, the current at the break (Figures 10 and 11) is not unreasonable. Nevertheless, the assurance of complete protection would not be reached unless a steady application of this current polarized the iron to -0.85 v (ref. Cu-CuSO₄) or to the open-circuit potential of the zinc on the experimental pipe section.

The idea of eliminating edge effects by the use of the copper-iron ball couple is novel, but again in evaluating the significance of the break in the polarization curve (Figure 12) the total corrosion occurring on the couple must be considered. Going back to the 1.9 ma/ft.² as a reasonable corrosion rate for iron in the high resistivity soil, the local action current on the 4.5-inch diameter steel ball surface would be about 0.84 ma. This local action current multiplied by a factor over 1, the factor depending on the control of the corrosion reaction, must be added to the applied current (0.75 ma) at which the Fe-Cu current becomes zero. The current (2.2 ma) at the break represents the applied current required to stop both the galvanic current and the local action current on the steel ball.

References

1. R. B. Mears and R. H. Brown. *Trans. Electrochem. Soc.* **74**, 519 (1938).
2. Melvin Romanoff. *Underground Corrosion*, National Bureau of Standards Circular 579 (1957).

Comments by E. W. Haycock, Shell Development Co., Emeryville, Calif.:

Mr. Sudrabin's paper serves to demonstrate once again the shortcomings of the current-potential break criterion for cases of corrosion other than those under cathodic control. Some twenty years ago, when this criterion was being introduced as a cathodic protection method, the restrictions on its use were clearly stated by Mears¹ and Brown. The use of this criterion has been discussed extensively, as Mr. Sudrabin points out and it is valuable to emphasize the conditions which must be assumed whenever this criterion finds practical application.

I would like to ask Mr. Sudrabin if he has any information on the anodic polarization curves of zinc in an environment similar to that of the tests he describes, especially insofar as it might be compared with the anode polarization of steel under the same circumstances. Zinc and steel must have similar anode polarization characteristics if the model he describes is to be compared with a pipe line system having steel anodes, especially in comparisons involving the use of the potential-current break criterion.

Reference

1. R. H. Brown and R. B. Mears. *Cathodic Protection. Trans. Electrochem. Soc.* **81**, 455 (1942).

Reply by L. P. Sudrabin and F. W. Ringer:

The discussions by Haycock, Husok, Schwerdtfeger and Tatum show cathodic protection criteria can be much more complex than the mere statement that a certain pipe-to-reference electrode potential will assure corrosion control.

A great need exists for well planned and objective fundamental research to establish the conditions that must be achieved for complete corrosion control by cathodic protection. There is further need to relate these fundamental requirements for corrosion control to the multitude of corrosion cell circumstances that can occur on a pipeline.

A major problem in a program to establish the significance of a criterion of protection is its simultaneous comparison with some direct measure of corrosion control.

The authors have been particularly concerned with the implicit faith placed upon the significance of the "apparent" break in a polarization curve. It has been stated² that "The intersection of the projections of the straight lines indicates the current required to reverse the potential of all anodic areas: i.e., the current required to prevent corrosion." The authors feel that their reported observations question the universality of this conclusion.

The steel ring-zinc plug corrosion system discussed by Mr. Schwerdtfeger should provide an interesting example of the importance of the geometrical relationship of the anode and cathode upon the current requirements. Consider the possibility of moving the zinc plug outside the steel ring, a distance equal to the radius, so that more of the IR drop from the applied current is included in the cathode polarization effect. The corrosion current flow from

the zinc may then become zero before an "apparent" break occurs in the polarization curve.

Although the average Faraday equivalent corrosion current for the five high resistivity soils mentioned by Mr. Schwerdtfeger is 1.9 ma/ft.², the actual values ranged over ten fold; i. e., 0.48 to 4.6 ma/ft.². The authors do not feel that this wide range of actual corrosion experience is consistent enough for comparing criteria. We have no data on the actual corrosion rate at the test site.

It is noted that the studies of Mr. Schwerdtfeger,^{20,38} have been conducted in soils and waters having resistivities less than 1000 ohm cm. It is felt that further useful observations would be made if the continued the studies in higher resistivity environments under conditions where the corrosion rate is largely controlled by the electrolyte resistance, rather than by polarization. A bare steel pipe surface in well aerated high resistance environment with a few small anodic areas caused by O₂ shielding effects of widely distributed contacting clay particles is an example of a case where a practical criterion of protection is not easily established.

The authors do not concur with Mr. Husock that the corrosion of iron is under cathodic control.

Mears¹³ has stated that cathodic control is "... a very special condition which would not be expected to obtain generally."

When corrosion is under cathodic control, we can expect:

- (a) The potential of the corroding system is open circuit potential of the anode.
- (b) The protective current requirements are equal to the corrosion current.

Neither of these conditions exist for corroding pipelines buried in generally well aerated high resistivity soils and waters where the corrosion rate is partly controlled by the electrolyte resistance and the potential may, for example, be -0.4 volts measured against a CuSO₄ reference electrode. When a pipeline approaches cathodic control, potentials of -0.75 volts or higher will be observed.

In the studies made by Schwerdtfeger²⁰ using more conductive environments (ρ 218 to 821 ohms cm) the ratio of corrosion current (i_0) to the protective current required (I_p) ranged from 0.78 to 0.88. These data indicated that the corrosion process only approached cathodic control.

In answer to Dr. Haycock, the authors have not made anodic polarization curves for the zinc anode or the steel pipe at the test site. The data in Table 6 show comparatively little anodic polarization of the zinc anodes. The authors wonder if the interpretation of anodic polarization curves may not have some of the same limitations observed in cathodic polarization curves.

In answer to Mr. Tatum and Mr. Husock, zinc anodes were used to produce the elements of potential, resistance, current flow distribution and geometrical conditions that do occur on a corroding surface of pipe. Since these elements are not a function of the material used to create them, magnesium discs or carbon discs, with an external battery, could have been used to demonstrate the principles.

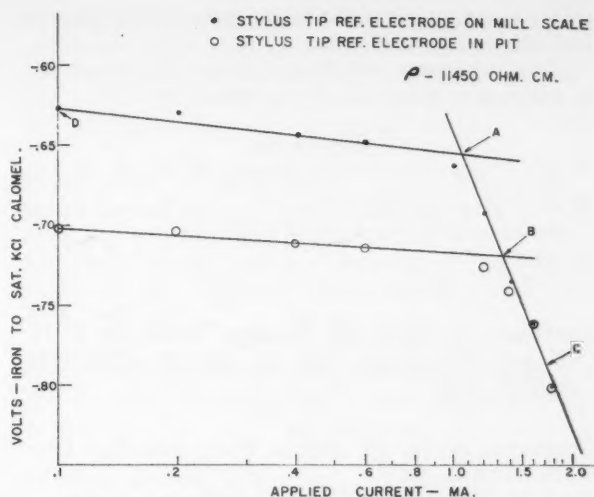


Figure 14—Polarization of steel in Belleville, N. J. water

The insertion of the current measuring meter has a negligible effect on the "true" conditions. The internal resistance of the ammeter is incomparably low with respect to the resistance between the zinc anodes and pipe as shown in Table 3 of the paper.

The authors are aware of the complexity of criteria pointed out by Mr. Tatum. The purpose of their work was to clarify the validity of various criteria commonly used.

About ten years ago, one of the authors conducted a polarization study with a hot rolled steel panel immersed in Belleville, New Jersey tap water. A few anodic areas, about 0.5 cm. in diameter, developed at weak points of the mill scale coated panel surface. Polarization curves were developed simultaneously with one stylus tip saturated KCl calomel reference electrode positioned in a corroding pit and another on the mill scale within one centimeter of the pit (Figure 14). The potential of the corroding panel to a third reference electrode five centimeters from the panel "D" corresponded closely to the potential of the mill scale and subsequent tests using the Pearson "Null" Method showed the panel polarization curve to compare closely to the potentials measured on the mill scale. Further tests indicated that with current applied to maintain the panel potential at "B" (-0.70 volts) rust continued to form and accumulate at the pit. When the potential of the panel was maintained at "C" (-0.78 volts) no further rust appeared to form.

These observations indicated that:

(a) Corrosion was not controlled at the potential of "apparent" break "A." Accumulation of ampere hour effects, at this applied current, may or may not eventually result in adequate or excessive protective effect.

(b) Corrosion was not controlled at the potential of "apparent" break "B." It is probable that the anode potential measured includes the effect of the closely coupled cathodes within the gross anodic area of the pit.

(c) Visual evidence approaching complete corro-

sion control occurred when the panel potential was maintained at -0.78 volts.

(The references and figure in this discussion are in addition to those listed in original article.)

References

37. Kirk Logan. *The Petroleum Engineer*, 14, No. 10, 168, 175-80 (1943).
38. W. J. Schwerdtfeger. *Jour. of Res. of the National Bureau of Standards*, 58, No. 3, 145-53 (1957).

Corrosion in Light Oil Storage Tanks by E. H. Tandy. *Corrosion*, Vol. 13, No. 7, 427t-432t (1957) July.

Comments by Ivy M. Parker, Plantation Pipe Line Co., Atlanta, Ga.:

I would like to compliment Mr. Tandy on the excellent paper he gave at the Western Regional Meeting in 1956. We on the Gulf Coast have been interested in this problem for some time and appreciated greatly Mr. Tandy's working out some of the problems and theories.

There are three or four items which I do not feel were covered in this report that we feel are of great importance. Mr. Tandy mentioned the fact that the finished products were not responsible in themselves for corrosion nor did they participate in the corrosion. However, the one serious item that was missing from the report was the fact that there has been in the last six or seven years a greatly increased rate of corrosion in these tanks. This, we feel is due primarily, to the fact that finished products have been improved greatly by refineries and consequently retain less or practically no gums or residuals after evaporation. This would tend to leave the surface clean and free for oxygen and water to attack the steel.

On the Gulf Coast two tanks in identical service, one for 26 years and one for seven years, both collapsed within two weeks of each other. On examination they showed practically identical conditions and corrosion rates and corroded areas described by Mr. Tandy were found in these tanks with the exception of the supporting columns of the cone deck. Webs of supporting beams in cone decks had the same corrosion rate practically all the way down and this we attributed to another item that Mr. Tandy did not include in his report that is, stress on the steel would seem to cause an increased rate of corrosion. On the supporting beams, the webs had completely corroded through; whereas, the flanges had 50 percent of the steel left. The corrosion rate was much greater on the webs than on the flanges and this has led us to believe that flaking off due to flexing under stress is a cause of added corrosion. This is borne out also in the corrosion rate in floating deck tanks where the greater stress is in the lower third of the shell.

Another point that I would like to make is that reports have come in from the Great Lakes area indicating that corrosion rates on tanks in fresh water areas are also dangerously high. This would

tend to minimize the effect of the salt in the moisture being breathed in the tanks. We realize that salt will increase conductivity but other data indicate corrosion will go on without salt.

Dick Clark of Atlantic Refining has additional information on this subject in relation to floating deck tanks. W. B. Cook of Gulf Refining has additional information on cone deck tanks. Undoubtedly there are other people in the refinery business who would have other and interesting information on this subject.

Reply by E. L. Tandy, Standard Oil Co. of Cal., El Segundo, Cal.:

We have noticed in recent years what appears to be an appreciable increase in corrosion rates in light oil storage tanks. Because the data were incomplete and it will be several years before firm corrosion rates can be established, no mention of this was made in the paper. It is our opinion that the use of more light components in present day gasolines is responsible. Their capacity for oxygen is greater and, therefore, they tend to promote higher corrosion rates. Other factors, too, have not been evaluated. For instance, most tanks with propeller type mixers appear to have a higher corrosion rate than those without.

Corrosion of the roof support columns has occurred at about the same rate as that for the shells. While it is true that stress is a corrosion accelerator, we have not felt that it had an appreciable effect on tank corrosion. Probably the best proof of this is the fact that there does not appear to be any accelerated corrosion adjacent to the welded seams. Cold driven rivets do sometimes suffer more attack than the adjacent plate but this is not general. The most damaging stress effect should occur in out-of-round tanks. Here the flexing of the shell would cause the scale to crack and sluff off. However, since it is our belief that the scale itself is a corrosion accelerator through its sponge and insulating effects, anything that would cause it to sluff off would probably decrease rather than increase the corrosion rate.

Failure of Steel-Admiralty Duplex Condenser Tubes by Hydrogen Penetration by H. E. Honkala and E. A. Wright. *Corrosion*, Vol. 13, No. 8, 501t-504t (1957) August.

Question by George A. Nelson, Emerville, Cal.:

What was the ultimate method used for preventing collapse of the Admiralty tubes?

Reply by H. E. Honkala and E. A. Wright:

Duplex tubes were replaced with steel condenser tubes and the cooling tower water was treated to reduce its corrosive action. From a practical standpoint, this was the most logical solution.

Question by N. T. Gourlie, Standard Oil Co., Wood River, Ill.:

You spoke of installing duplex tubes by first rolling the steel portion of the tubes into the tube sheets

and then installing Admiralty ferrules. If ferrules are not used is it possible to roll the Admiralty liner of these tubes simultaneously with the steel portion? If so, are there any special rolling procedures necessary?

We are afraid the Admiralty portion of the tube will gall or twist up inside the steel during rolling.

Reply by H. E. Honkala and E. A. Wright:

To answer this question adequately, I will briefly describe the manufacture of duplex tubes. The liner and OD tube are mechanically bonded together by expanding the liner into the OD tube, sinking the OD tube onto the liner, or a combination of both of these operations. If the tube is to have ferrules made of the same material as the liner, the OD tube would be precut to an exact length. The liner material would extend past the ends of the OD tube enough to accommodate the ferrules. The ferrules are installed by mechanically bonding and the finished tube is then cut to exact length. All of these operations are performed by the tube fabricator.

My statement regarding the rolling-in procedure was probably not made very clear. The Admiralty ferrules were fabricated so that they would extend about half-way through each tube sheet. The fabricator of these condensers stated that the part of the tube with the OD steel portion was rolled into the tube sheet first and then the entire unit was tested for leaks before all Admiralty ferrules were rolled in. This particular point was questioned by the authors in order to eliminate leakage between the duplex tubes during operation.

The steel and Admiralty tubes can be rolled together in one operation. With reduced thrust pressure and slower rolling speeds, no trouble should be encountered with twisting or galling of the Admiralty liner.

Question by Mills Dean III, Navy Dept., David Taylor Model Basin, Washington, D. C.:

As an aid to eliminate collapse of the inner tube was there correlation in reducing failure by increasing the wall thickness?

Reply by H. E. Honkala and E. A. Wright:

Other investigations of hydrogen blistering have shown that pressure build-up in small defects will exceed the yield strength of the steel. It also has been shown that several inches of steel can be penetrated by atomic hydrogen in a relatively short time if the proper environmental conditions are present.

Properties and Performance of Reinforced Polyester Plastics in the Chemical Industry by R. E. Gackebach and Donald G. Estey. *Corrosion*, Vol. 13, No. 8, 546t-552t (1957) August.

Question by Robert J. Sarraf, Rockwell Mfg. Co., Pittsburgh:

What are toxicological, odor and taste producing effects imparted by use of various plastic types

covered (thermoplastic, thermosetting, reinforced polyesters, etc.) when used as materials of construction for piping and associated equipment for handling of potable and food products, and specifically in handling of domestic (drinking) water?

Reply by R. E. Gackebach:

Laminac 4111 as fabricated by Haveg Industries under Haveg 7730 has been approved by the Food and Drug Administration as having no toxicological properties and being suitable for certain potable and food products.

Question by Charles N. Cresap, White Plains, N. Y.:
Are cyanurate polyesters effective as adhesives, steel in particular?

Reply by Donald G. Estey:

Cyanurate resins are not good adhesives and would not be used on steel.

Question by Lewis W. Gleekman, Wyandotte Chemical Corp., Wyandotte, Mich.:

Have developments been made recently in improving the adhesive strength of the polyesters relative to the epoxy resins? Is the adhesive strength of a resin, reinforcing glass cloth, of major concern in wrapping steel lines?

Reply by Donald G. Estey:

There have been no recent modifications of polyesters to make them comparable to epoxies in adhesive properties.

For wrapping steel pipe lines, glass cloth reinforced polyesters have shown adequate adhesion to be successful for the application.

Question by Edward G. Brink, American Viscose Corp., Marcus Hook, Pa.:

The flammable characteristics of plastics become an important factor in the design of duct systems insofar as fire insurance underwriters are concerned. What progress has been made in improving the fire resistant characteristics of the polyester plastics for services of this type?

Reply by R. E. Gackebach:

There are two types of fire retardant polyesters available. One type utilizes the addition of antimony trioxide to a specially compounded polyester. The other has a chlorine atom attached to the polyester molecule. Both types have been approved by various fire insurance underwriters.

Question by John W. Carrow, Wilmington, Del.:

Does the armoring of glass and/or Karbate pipe, with polyester-glass, or epoxy glass, permit higher operating pressure recommendations for the pipe?

Reply by R. E. Gackebach:

To the best of my knowledge, the use of polyester-glass or epoxy-glass armoring will not alter the pressure ratings on glass pipe. However, I believe it will

allow higher pressures in Karbate pipe. This last matter will require some investigation.

Question by Louis M. Nielowski, Wilmington, Del.:
How do you insert nipples in a reinforced polyester vessel in the field?

Reply by R. E. Gackenbach:

Reinforced polyester nipples are readily inserted into a reinforced polyester vessel. First a hole $\frac{1}{4}$ -inch larger than the outside diameter of the nipple is cut in the vessel. The edges are beveled on both sides. After the outside surface of the nipple is sanded or roughened, it is inserted in the hole. The annular space is filled with polyester cement and all edges beveled or feathered. This unit may be put into service after complete cure of the resin cement.

Corrosion of Aluminum-Nickel Type Alloys In High Temperature Aqueous Service by F. H. Krenz. *Corrosion*, Vol. 13, No. 9, 575t-581t (1957) Sept.

Question by R. McFarland, Hills McCanna Co., Chicago:

With reference to the slide showing failure of metal in a wave or erosion pattern adjacent to the weld, what method was used to calculate the probable frequency of oscillation of the sample to arrive at 4000 CPS?

Reply by F. H. Krenz:

Frequency was estimated from the separation between "nodes" on the metal surface and the water velocity in linear feet per second. This last was 20 fps for the tests under consideration and the spacing of the ridges on the specimen was such that in 20 feet there would have been approximately 4000, that is, 4000 ridges per second. This was, of course, only an approximate figure.

Question by T. C. Hoppe, Kansas City:

In discussion of the corrosion rates of alloys 55 and 57, one of the conditions mentioned was the velocity of 18 to 20 feet per second. Were any corrosion data obtained at lower velocities, such as 5 to 7 feet per second?

Reply by F. H. Krenz:

Several runs were made at 2-3 fps. The results were intermediate between those of static tests and those of tests at high flow velocities. Corrosion rates were of the order of 7-10 mils/year.

Question by Ralph J. Lobsinger, Richland, Wash.:

In regard to the remarks made on velocity considerations in the corrosion of aluminum, it has been observed in high temperature tests at Hanford that velocities above 2 feet/second did not greatly increase corrosion rates on aluminum. The tests were made in static autoclaves and in dynamic loops with velocities up to 20 feet/second.

Reply by F. H. Krenz:

Results obtained at Hanford have been made known to us, thanks to the friendly cooperation of the USAEC and we find that their results at 20 fps can be extrapolated to our working temperatures to give very satisfactory agreement with our own results. We find, however, a discrepancy between the observation mentioned by Mr. Lobsinger and our own observations at 2-3 fps (see above) in that we find a very appreciable increase in corrosion rate on going from 2-3 fps to 20 fps, i.e., from 7-10 mils/year to about 50 mils/year.

Corrosion of Aluminum in High Purity Water by R. J. Lobsinger and J. M. Atwood. *Corrosion*, Vol. 13, No. 9, 582t-584t (1957) Sept.

Question by Robert D. Misch, Argonne National Laboratory, Lemont, Ill.:

The use of phosphoric acid has a scientific basis which was considered by W. E. Ruther of Argonne National Laboratory when this additive was first studied. Chromatographic work on the adsorption of inorganic anions on alumina has shown that phosphate ion follows hydroxyl ion in strength of adsorption. Since film breakdown is probably associated with the incorporation of hydroxyl ion the presence of phosphate ion should help to protect the film by screening the surface.

Reply by R. J. Lobsinger:

It is recognized that W. E. Ruther did the initial work which led to the studies of phosphoric acid as an inhibitor for aluminum. Evidence at Hanford suggests, however, that the mechanism of inhibition is not caused by mechanical adsorption. Rather, a new corrosion product is formed on aluminum exposed to pH 4.5 phosphoric acid. This corrosion product was found by X-ray diffraction to be augelite ($2\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 3\text{H}_2\text{O}$ or $\text{Al}_2\text{PO}_4(\text{OH})_3$). No boehmite ($\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$) or other aluminas were found. It is not known as yet if the phosphoric acid inhibits by producing a stronger corrosion film or by affecting the diffusion of aluminum ion through the corrosion film.

Question by T. C. Hoppe, Kansas City, Mo.:

Was the normal pH 5.3 to 5.6 the result of regenerating the mixed bed with HNO_3 and the normal pH of 5.8 to 6.2 the result of regenerating with H_3PO_4 ?

Reply by R. J. Lobsinger:

The corrosion data were obtained by exposure of the aluminum alloys to three different types of water. Initially high purity water was used. This water was obtained by cleanup of a portion of the loop flow through a mixed-bed ion-exchange resin and had a pH range of 5.8 to 6.2. A second series of tests was performed at a pH range of 5.3 to 5.6. This range was obtained by cleanup of a portion of the loop flow through the HNO_3 regenerated cation resin. The

third test was performed at a pH range of 4.5 to 5.0 which was obtained by direct injection of phosphoric acid.

The Storage of High Purity Water by Richard R. Dlesk. *Corrosion*, Vol. 13, No. 9, 585t-588t (1957) Sept.

Questions by R. E. Gackenbach, American Cyanamid Co., Bound Brook, N. J.:

1. Was the metallized aluminum surface sealed with a material like vinyl or silicone?
2. You mentioned a rubber base coating. Was that coating a catalyzed neoprene?

Replies by Richard R. Dlesk:

1. The aluminum was unsealed. While recognizing the need for a sealer to reduce the porosity of sprayed metal coatings, we have been unable to find one that is entirely satisfactory.

We feel that a sealer must meet the following important criteria: (1) Must be effective in reducing porosity. (2) Must be stable at temperatures up to 160 F. (3) Must not contaminate the feed water. (4) Must be economical to purchase and apply.

2. Yes.

Question by A. Oscar Blatter, Union Electric Co., St. Louis:

Do you insulate the iron pipe from the aluminum tanks to prevent galvanic action?

Reply by Richard R. Dlesk:

The iron pipe is not insulated from the aluminum. It was felt that because of the high resistivity of the water (500,000 ohm-cm) any galvanic action which would take place would be minute. No detectable amount of galvanic corrosion has been found.

Comments by E. F. Bladholm, Southern California Edison Co., Los Angeles:

This subject is of particular interest to the Southern California Edison Company as we have a number of distilled water tanks and the protective coatings have been a particular problem in these tanks. Mr. Dlesk has outlined accurately the feedwater requirements for a modern steam station and there is little which can be added to that part of the story. He mentioned one of the important features of a protective coating; that it should not contaminate the feedwater.

During the inspection of our No. 1 distilled water tank at Redondo Steam Station after about seven years' service, there was only moderate rusting of the surface as a whole. It had been coated with a phenolic red lead primer with a phenolic aluminum top coat. Most of the aluminum color was still present. Inspection of the surface showed the coating was powdery and could be removed easily by rubbing the surface. It was concluded that since the pigment

remained, the phenolic resin vehicle must have dissolved in the water.

We have had some failures of boiler tubes which were caused by the rupture of blisters. Investigation showed that scale was present on the inner wall of the tubes. Analysis of the scale showed an ignition loss of about 40 percent. The question was asked: "what does the 40 percent represent?" Is it attributable to resins which are leached out of the coatings? We have been giving this some thought in recent months and are endeavoring to find the answers.

If it can be found that the materials which are leached out of the protective coatings in the distilled water, deaerator storage, condensate and other tanks in the condensate-feedwater system contribute to the boiler scale, perhaps the saving of one boiler outage will pay for the use of non-corrosive alloy materials for those tanks. It would be interesting to know if the author, or others in the utility field, have done any research along these lines.

We are also using a high grade phenolic coating in more recent distilled water tanks, and so far, this material appears hard and good. The service life to date is about three years.

The author referred to a metallic zinc coating. We are using such a product on four of our distilled water tanks but have not had sufficient operating experience to determine its effectiveness. Our company currently has several coated panels on test in a condensate detention tank at Redondo Steam Station. This is condensate from the fuel oil heaters and the temperature is around 170 to 180 F. We have also three aluminum samples immersed in a distilled water tank. The results, after about one year's immersion, appear satisfactory. We have not used metallized aluminum as a coating for this purpose because we have felt that this type of surface is porous. There is one such coating which is treated with a silica solution after metal spraying but we rejected this proposal because of the possibility of adding silica to the feedwater system. The author is to be congratulated on this complete report. We are all interested in aluminum storage tanks and this paper and experience of the author's company is of considerable value to the industry.

Reply by Richard R. Dlesk:

Mr. Bladholm has given an interesting example of one of the many unexpected and perplexing problems that can arise with the storage of high purity water. Fortunately, we have escaped the phenolic-resin leaching problem.

Corrosion of Austenitic Stainless Steels in Sulfuric Acid by E. H. Phelps and D. C. Vreeland. *Corrosion*, Vol. 13, No. 10, 619t-624t (1957) Oct.

Question by D. K. Priest, Rochester, N. Y.:

How can the authors account for the great difference in corrosion rates brought about by wet and dry grinding preparation? Were the results based on one test period or several test periods?

Reply by E. H. Phelps:

The difference in metal surface temperature achieved during the wet and dry grinding operations may have resulted in different surface stresses in the samples prepared by the two types of grinding. This difference in surface condition may account for the difference in corrosion behavior obtained. The results obtained were based on one test period.

Question by Thomas W. Moore, E. I. duPont de Nemours & Co., Inc., Penns Grove, N. J.:

What work has been done to determine corrosion rates of austenitic stainless steels in the concentration range of 100 percent H_2SO_4 and above in the temperature range of 150-200 C?

Reply by E. H. Phelps:

The maximum concentration of acid used in the present work was 96 percent by weight and the temperature range covered was 30 to 70 C. We have not done any work on the corrosion resistance of aus-

tenitic stainless steels in the concentration and temperature ranges mentioned.

Question by I. Rozalsky, Shell Oil Co., Roxana, Ill.: Regarding your comparisons between Types 304 and 316 stainless steel corroded by sulfuric acid, what do you consider to be the mechanism by which molybdenum modifies the transition from the passive to the active condition for stainless steels?

Reply by E. H. Phelps:

Rhodin¹ has shown that molybdenum is present in films formed on Type 316 stainless steel by acid pickling and passivating treatments. This observation indicates that molybdenum in the alloy may play a part in the film forming process and may account for the marked influence of molybdenum on the transition from the active to the passive state observed in the present work.

Reference

1. T. N. Rhodin. Oxide Films on Stainless Steel. *Corrosion*, **12**, No. 3, 123t-135t (1956) Mar.

Discussions to technical articles appear in the June and December issues only when they do not immediately follow the article to which they pertain. Discussions received from December through May will appear in the June issue and those from June through November in the December issue.



TECHNICAL COMMITTEE ACTIVITIES

Two Hydrogen Sulfide Reports to Be Published

Catalytic Reformer Data Approved By Refinery Group

A report titled "Compilation and Correlation of High Temperature Catalytic Reformer Corrosion Data" has been prepared by G. Sorrell, of M. W. Kellogg Company, New York City and presented to Group Committee T-8 on Refinery Industry Corrosion as a contribution to the work of the committee.

Although not a formal NACE Technical Committee report, it was prepared in conjunction with the work done by Task Group T-5B-2 on Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry which has been absorbed in the newly formed Group Committee T-8.

In the survey report on high temperatures catalytic reformer corrosion, data contributed by 15 petroleum refining companies includes results obtained from laboratory, pilot plants and commercial plant corrosion studies as well as inspection measurements on operating equipment. Correlations directly applicable to equipment design are presented.

Corrosion is attributed to small quantities of hydrogen sulfide in the hydrogen-rich gas mixtures. The principal variables affecting the rate of attack are temperature and hydrogen sulfide concentration. Other factors such as pressure, hydrogen content, time of exposure, cycling conditions and scale properties also are discussed in relation to their effect on corrosion.

Data in the report show conclusively that carbon and chromemoly steels are equally resistant to sulfide attack. The intermediate straight chrome steels (11% to 16% chromium) show a moderate but generally unreliable degree of improvement. The austenitic chromium-nickel stainless steel have a good resistance. Aluminum coatings applied by dipping, spraying or diffusion methods exhibit outstanding corrosion resisting properties provided the coating is continuous and remains permanently bonded to the steel. The paper concludes with a general review of catalytic reformer corrosion problems, including a brief discussion of corrosion mitigation by hydrogen sulfide removal (amine treating) or catalytic desulfurization of the feed.

The report has been approved by the chairman of Group Committee T-8, the chairman of the Technical Practices Committee and by the Editor of CORROSION for publication in the January, 1958 issue of CORROSION.

Reinforced Acid Brick Lining Report Approved

Unit Committee T-6A has completed review of a report on reinforced (acid brick/resin cement) lining. The report

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McConnell Heads T-6J On Coatings Application

Fred M. McConnell, Service Coating Corp., Wilmington, California, has been elected chairman of Technical Unit Committee T-6J, Los Angeles Area, Protective Coating Application Problems. Newell Tune, Dept. of Water & Power, Los Angeles, California, was elected vice-chairman and Paul C. Briley, National Lead Co., Los Angeles, California, assistant secretary.

Ivan Sullivan, Spence & Sullivan Inc., Torrance, California, recently resigned as chairman of Technical Unit Committee T-6J due to his health.

Technical Unit Committee T-6J will hold a full committee meeting 6:30 p.m. December 5, 1957, at the Rodger Young Auditorium. Plans will be made for the meeting in March 1958 in San Francisco. A great deal of interest in the activities of the committee is anticipated from other regions.

Surface Preparation Draft Is Prepared

The Painting Specifications Task Group of Unit Committee T-6D on Industrial Maintenance Painting has prepared a draft of a specification for surface preparation and material application for industrial maintenance painting. A preliminary draft was presented to Unit Com-

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Resistance of Stainless Steels Is Investigated

A paper titled "High Temperature H₂S Corrosion of Stainless Steels" by E. B. Backensto, R. D. Drew, J. E. Prior and J. W. Sjöberg of Socony Mobile Oil Company, Inc., Paulsboro, New Jersey has been presented to Group Committee T-8 on Refinery Industry Corrosion as a contribution of the work of that committee. The paper was presented at the NACE North Central Region Refinery Industry Symposium in Chicago October 3 of this year.

Abstract of the paper reads as follows: In recent years the petroleum industry has been plagued with a number of high temperature H₂S corrosion problems, primarily in connection with catalytic reforming. To combat this problem from the standpoint of materials selection, only the austenitic steels offer satisfactory resistance to this type of attack under a wide range of conditions.

This paper reports the results of laboratory investigations chiefly on stainless steels, covering the following main topics: 1. The possible application of the new manganese-modified stainless steels. 2. The effect of heat treatment on corrosion rate. 3. The comparison of corrosion rates of wrought, weld, and cast stainless steel. 4. Some tests on stress corrosion cracking.

The paper has been approved by T-8, the chairman of Group Committee T-8, the chairman of the Technical Practices Committee and the editor of CORROSION for publication in the January, 1958 issue of CORROSION.

25 Reports Printed in '57; 26 More Ready in 1958

Twenty-five technical committee reports were published in 1957 issues of CORROSION. So far 73 technical committee reports have been published since the committees were organized in 1946. In March of this year the NACE Technical Practices Committee decided that beginning with the reports published in 1957 they would be made available in bound volumes covering a two-year period. First of these bound volumes, available in 1959, will include all reports published in 1957 and 1958.

The outlook for publication of technical committee reports in 1958 is bright. It is anticipated that reports on the following subjects will be published in 1958 issues of CORROSION.

1. High Pressure Well Completion and Corrosion Mitigation Procedures.
2. Oil Field Structural Plastics.
3. Sour Crude Inhibitor Evaluation.

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TECHNICAL ARTICLES SCHEDULED IN JANUARY

Corrosion and Metal Transport in Fused Sodium Hydroxide, III, Formation of Composite Scales on Inconel by G. Pedro Smith, Mark E. Steidlitz and Eugene E. Hoffman

Cavity Formation in Iron Oxide by D. W. Juenker, R. A. Meussner and C. E. Birchenall

The Effect of NO, HNO₂ and HNO₃ on Corrosion of Stainless Steel by H₂SO₄ by W. P. McKinnell, Jr., L. F. Lockwood, R. Speiser, F. H. Beck and M. G. Fontana

The Oxidation of Molybdenum by J. F. Mosher, E. S. Jones, Rudolph Speiser and J. W. Spretnak

Corrosion of Metals in Tropical Environments by B. W. Forgeson, C. R. Southwell, Allen L. Alexander, H. W. Mundt, (Deceased) and L. J. Thompson

Structural Features of Corrosion of Al-Alloys in Water at 300°C by Kurt M. Carlsen

A Kinetic Study of Acid Corrosion of Cadmium by Henry Weaver, Jr. and Cecil C. Lynch

Breakaway Oxidation of Zirconium-Tin Alloys by E. A. Gulbransen and K. F. Andrew

Fuel Ash Attack on Aluminum Stainless Steel by J. E. Srawley

Galvanic Corrosion of Aluminum-Steel and Aluminum-Lead Couples by M. J. Pryor

25 Reports—

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4. Sweet Crude Inhibitor Evaluation.
5. Cathodic Protection Ground Bed Design.
6. Use of High Silicon Cast Iron for Anodes.
7. Criteria for Cathodic Protection.
8. Internal Pipe Lining with Asphalt Type Protective Coatings.
9. Specifications for Wrappers for Underground Pipe Line Coatings including Asbestos Felt, Glass Wrap, Glass Base Outer Wrap and Rag Felt.
10. Tentative Specifications and Application Procedures for Prefabricated Plastic Film for Pipe Line Coatings.
11. Part III of the Corrosion Products Bibliography.

12. Electrical Holiday Inspection of Coatings.
13. Corrosion of Railroad Hopper Cars.
14. A Symposium on High Purity Water.
15. A Report on Corrosion by Nitric Acid.
16. A Report on the Status of the Oil Ash Corrosion Problem.
17. Plastic Materials of Construction for Use in the Chemical Process Industry.
18. Phenolic Coatings.
19. Protective Coatings for Resistance to Marine Corrosion.
20. Industrial Maintenance Painting Programs.
21. Corrosion Problems in H. F. Alkalization Units.
22. Zero Resistance Ammeter for use in Electrolysis Testing Work.
23. Coal Tar Base Linings.
24. Reinforced (faced) Tank Linings.
25. High Temperature H₂S Corrosion of Stainless Steels.
26. Compilation and Correlation of High Temperature Catalytic Reformer Corrosion Data.

Reinforced Acid—

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has been approved for publication. It includes a description of the various reinforced cement systems and their physical properties and resistance characteristics.

At the T-6A meeting in Oklahoma City October 1 the committee heard a report on the practical aspects of acid proof brick linings in general. Method of manufacture of bricks was reviewed briefly and the use of resinous membranes and cement in conjunction with acid proof brick was described. Limitations of acid proof brick linings, which are primarily their great weight and permeability, were discussed. Discussion from the floor after the presentation of the report revealed the fact that the brick linings are very costly and that corrosion resistant alloys are, in many cases, more economical.

T-6A has completed preliminary reviews of a report on coal tar linings. The committee suggested several revisions which were included in the report before it was resubmitted to the members. The committee anticipates it will be completed and ready to submit for publication before March, 1958.

A report on phenolic coatings also was presented to T-6A at the meeting in Oklahoma City. This was the first reading of the report which has been circulated to committee members for comment. The committee requires that all reports be read to the committee, circulated to the committee for comment, revised and re-circulated to the membership, then re-presented to the committee for final comment. If there are no further revisions, then the report is submitted to the committee for vote to be approved for publication.

Title of Task Group T-6A-16 has been changed from Bituminous Coatings to Coal Tar Coatings. A proposal has been made that a new Task Group T-6A-19 be formed to study asphalt coatings and linings.

Christmas Meeting Set

Metropolitan New York Section will hold its annual Christmas meeting Dec. 11 at the Shelburn Hotel in New York City. The guest speaker will be W. H. Stewart, president of NACE.

Maintenance Painting Post Resigned by J. C. Coffin

J. C. Coffin, Dow Chemical Company, Midland, Michigan has resigned as chairman of Unit Committee T-6D on Industrial Maintenance Painting. Mr. Coffin's resignation was made necessary by a change in his company responsibility with Dow Chemical Company. A committee has been appointed to select nominees to be voted on to replace Mr. Coffin. Vice-chairman of the committee, R. S. Freeman, Cities Service Refining Company, Lake Charles, Louisiana resigned as vice-chairman a short time before Mr. Coffin's resignation was submitted.

Surface Preparation—

(Continued From Page 95)

mittee T-6D at the committee's meeting in Oklahoma City October 2.

Scope of the specifications provides that they shall cover material, equipment and procedures for surface preparation and material applications for all painting and coatings performed at a specified plant. Essentially, the specification serves only as a general outline of specifications form and suggested topics. The detailed content and definitions must be provided by the company using the specifications. Suggestions are made to provide a guide to other items should be included. Contents are: 1. General. 2. Condensed Specification Methods. 3. Surface Preparation. 4. Pretreatment. 5. Material Application. 6. Material Description. 7. Inspection.

The Painting Program Task Group of Unit Committee T-6D sent out 900 questionnaires for information from industry on which to develop the painting program. About 20 percent of the questionnaires have come back. Data returned is to be analyzed and reported at the Unit Committee meeting in San Francisco in March, 1958.

The T-6D Task Group on Economics of Maintenance Painting has prepared a questionnaire to be sent to industries selected by area and type of operation. It is expected replies will influence the future work of the task group.

Compton Talks at New York On Atmospheric Corrosion

An analysis was made of the various factors contributing to atmospheric corrosion in a talk given by K. G. Compton at a Nov. 6 meeting of the Metropolitan New York Section. The meeting was held at the Chi-Am Chateau in Mountainside, New Jersey.

Mr. Compton drew on his long and broad experience in the field of corrosion in discussing the behavior of materials in a variety of atmospheric exposures. Data were presented on the effect of location and the type of test employed. Contamination combined with a persistent film of moisture was cited by Mr. Compton as being the principal cause of atmospheric corrosion.

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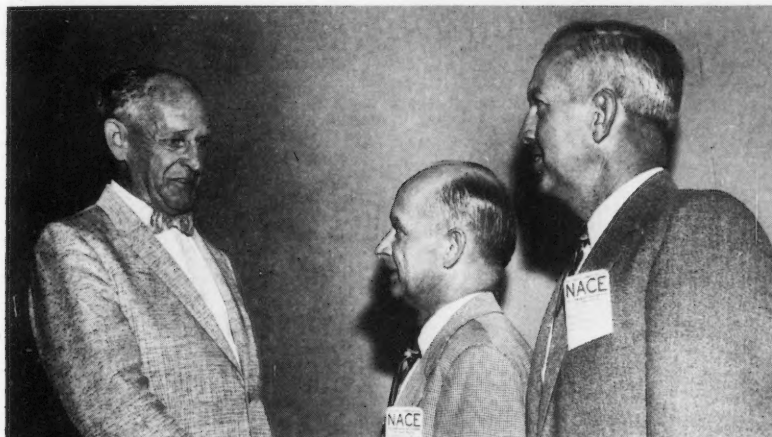
NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg. Houston 2, Texas



NACE NEWS

Short Course for Pipeliners Set at Houston



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25 Reports—

(Continued From Page 95)

4. Sweet Crude Inhibitor Evaluation.
5. Cathodic Protection Ground Bed Design.
6. Use of High Silicon Cast Iron for Anodes.
7. Criteria for Cathodic Protection.
8. Internal Pipe Lining with Asphalt Type Protective Coatings.
9. Specifications for Wrappers for Underground Pipe Line Coatings including Asbestos Felt, Glass Wrap, Glass Base Outer Wrap and Rag Felt.
10. Tentative Specifications and Application Procedures for Prefabricated Plastic Film for Pipe Line Coatings.
11. Part III of the Corrosion Products Bibliography.

12. Electrical Holiday Inspection of Coatings.
13. Corrosion of Railroad Hopper Cars.
14. A Symposium on High Purity Water.
15. A Report on Corrosion by Nitric Acid.
16. A Report on the Status of the Oil Ash Corrosion Problem.
17. Plastic Materials of Construction for Use in the Chemical Process Industry.
18. Phenolic Coatings.
19. Protective Coatings for Resistance to Marine Corrosion.
20. Industrial Maintenance Painting Programs.
21. Corrosion Problems in H. F. Alkalinity Units.
22. Zero Resistance Ammeter for use in Electrolysis Testing Work.
23. Coal Tar Base Linings.
24. Reinforced (faced) Tank Linings.
25. High Temperature H₂S Corrosion of Stainless Steels.
26. Compilation and Correlation of High Temperature Catalytic Reformer Corrosion Data.

Reinforced Acid—

(Continued From Page 95)

has been approved for publication. It includes a description of the various reinforced cement systems and their physical properties and resistance characteristics.

At the T-6A meeting in Oklahoma City October 1 the committee heard a report on the practical aspects of acid proof brick linings in general. Method of manufacture of bricks was reviewed briefly and the use of resinous membranes and cement in conjunction with acid proof brick was described. Limitations of acid proof brick linings, which are primarily their great weight and permeability, were discussed. Discussion from the floor after the presentation of the report revealed the fact that the brick linings are very costly and that corrosion resistant alloys are, in many cases, more economical.

T-6A has completed preliminary reviews of a report on coal tar linings. The committee suggested several revisions which were included in the report before it was resubmitted to the members. The committee anticipates it will be completed and ready to submit for publication before March, 1958.

A report on phenolic coatings also was presented to T-6A at the meeting in Oklahoma City. This was the first reading of the report which has been circulated to committee members for comment. The committee requires that all reports be read to the committee, circulated to the committee for comment, revised and re-circulated to the membership, then re-presented to the committee for final comment. If there are no further revisions, then the report is submitted to the committee for vote to be approved for publication.

Title of Task Group T-6A-16 has been changed from Bituminous Coatings to Coal Tar Coatings. A proposal has been made that a new Task Group T-6A-19 be formed to study asphalt coatings and linings.

Christmas Meeting Set

Metropolitan New York Section will hold its annual Christmas meeting Dec. 11 at the Shelburn Hotel in New York City. The guest speaker will be W. H. Stewart, president of NACE.

Maintenance Painting Post Resigned by J. C. Coffin

J. C. Coffin, Dow Chemical Company, Midland, Michigan has resigned as chairman of Unit Committee T-6D on Industrial Maintenance Painting. Mr. Coffin's resignation was made necessary by a change in his company responsibility with Dow Chemical Company. A committee has been appointed to select nominees to be voted on to replace Mr. Coffin. Vice-chairman of the committee, R. S. Freeman, Cities Service Refining Company, Lake Charles, Louisiana resigned as vice-chairman a short time before Mr. Coffin's resignation was submitted.

Surface Preparation—

(Continued From Page 95)

mittee T-6D at the committee's meeting in Oklahoma City October 2.

Scope of the specifications provides that they shall cover material, equipment and procedures for surface preparation and material applications for all painting and coatings performed at a specified plant. Essentially, the specification serves only as a general outline of specifications form and suggested topics. The detailed content and definitions must be provided by the company using the specifications. Suggestions are made to provide a guide to other items should be included. Contents are: 1. General. 2. Condensed Specification Methods. 3. Surface Preparation. 4. Pretreatment. 5. Material Application. 6. Material Description. 7. Inspection.

The Painting Program Task Group of Unit Committee T-6D sent out 900 questionnaires for information from industry on which to develop the painting program. About 20 percent of the questionnaires have come back. Data returned is to be analyzed and reported at the Unit Committee meeting in San Francisco in March, 1958.

The T-6D Task Group on Economics of Maintenance Painting has prepared a questionnaire to be sent to industries selected by area and type of operation. It is expected replies will influence the future work of the task group.

Compton Talks at New York On Atmospheric Corrosion

An analysis was made of the various factors contributing to atmospheric corrosion in a talk given by K. G. Compton at a Nov. 6 meeting of the Metropolitan New York Section. The meeting was held at the Chi-Am Chateau in Mountaintop, New Jersey.

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WESTERN REGION meeting technical session scenes: Top-left, John Stevens, Dow Chemical Co. answers questions from the floor while A. F. Hooper, Convair Div., General Dynamics Corp. moderates the Aircraft session; right, Frank Buck, Arizona Public Service Co. is introduced by R. E. Graham, San Diego Water Dept., chairman of the Utilities session. Bottom-left, D. B. Roach, Battelle Memorial Institute, Columbus, Ohio, (standing) delivers his paper on high temperature oxidation; Harry Hochman, U. S. Naval Civil Engineering Laboratory and W. E. Bowen, U. S. Naval Air Missile Test Center, chairman, are photographed during the Marine session.

Thirty-One Attend San Diego's Basic Corrosion Course

A Basic Corrosion course, aimed at a "down to earth explanation of corrosion and corrosion mitigation" for technicians and beginning engineers was presented by the San Diego Section beginning September 12 at the Alvarado Filtration Plant, City of San Diego Water Dept.

Students, enthusiastic about the course, reported it was truly on fundamentals. Many courses, even though considered basic by experienced engineers, are really too advanced for tyro engineers and technical personnel, it was felt. Instructors are now preparing a textbook to include the lectures and demonstrations and more complete technical data. A glossary will be included among the estimated 80 to 100 pages.

Thirty-one students enrolled for the four-session night classes taught by eight instructors. Passive films were explained by John Steihl, Norman Larsen lectured on theories of corrosion during the third session and Ken Christy described the effects of different types of waters in a water heater test made by the Corrosion Section of the City of San Diego.

Question and answer periods were combined with lectures. Some other instructors taking part in the lectures and panel discussions were Reuben Tullis, Loy Flor and Ambrose Nichols. Dan Nordstrom acted as moderator.

Corrosion Engineering Week Is Claimed

Mayor Charles C. Dial of San Diego declared the week of October 20-26 to be "Corrosion Engineering Week," in honor of the Western Region's Seventh Annual Regional Conference in that city October 23-25. Reuben Tullis, San Diego Section publicity chairman reported the proclamation helped the region get valuable publicity in newspapers and on radio and television stations.

The mayor's proclamation, citing the objectives of the National Association of Corrosion Engineers pointed to the estimated \$6,000,000 annual corrosion loss in San Diego and the loss of billions of dollars annually in the nation.

Young Author Award Contest Has 59 Qualified

Fifty-nine authors of technical papers published in CORROSION's Technical Section during 1957 have qualified for consideration in the competition to select the best paper published in the journal during the year by authors 35 years of age or less. Author of the paper judged best will be offered the 1957 Young Author Award, a gratuity of \$100. The award usually is made at the annual banquet in March.

Decision on the paper is made annually by a committee named by the NACE president. This year the committee is headed by Norman Hackerman, University of Texas and committee members are the same as those on the NACE Education Committee.

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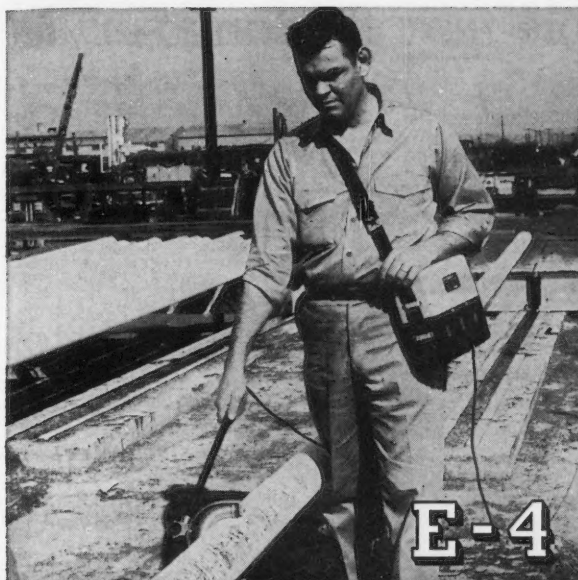
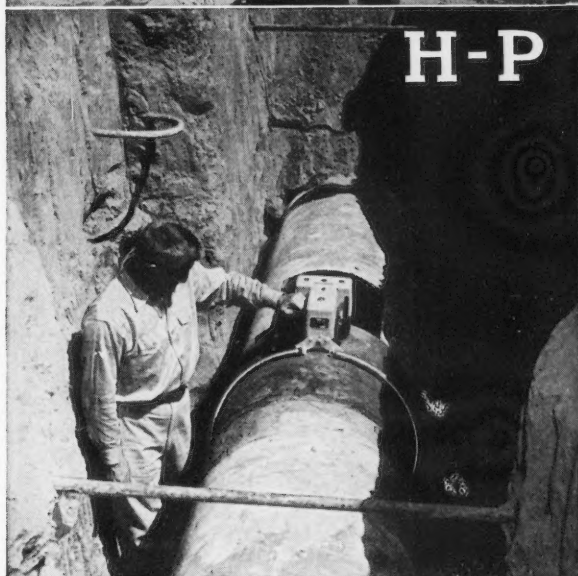
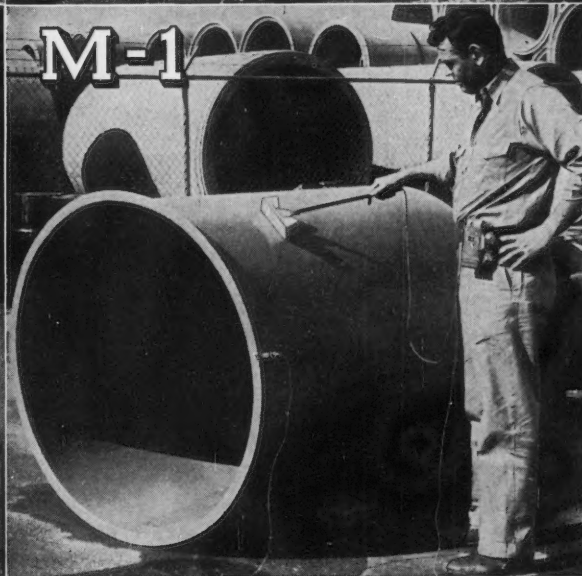
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- E-P** Holiday detector similar to E-4 but suitable for testing either wet or dry surfaces. The best general-purpose holiday detector made. Comes in sturdy carrying case with battery charger.
- H-P** Pipeline "Jeep" for field testing wrappings and field joints on transmission pipelines 4 to 36-inch diameter. Fully portable. Has own power supply. No generator needed. Creates a working voltage 12,000 to 15,000-v. Not hot spark. No trailing ground wire. Virtually shockproof. Snap-off electrode.
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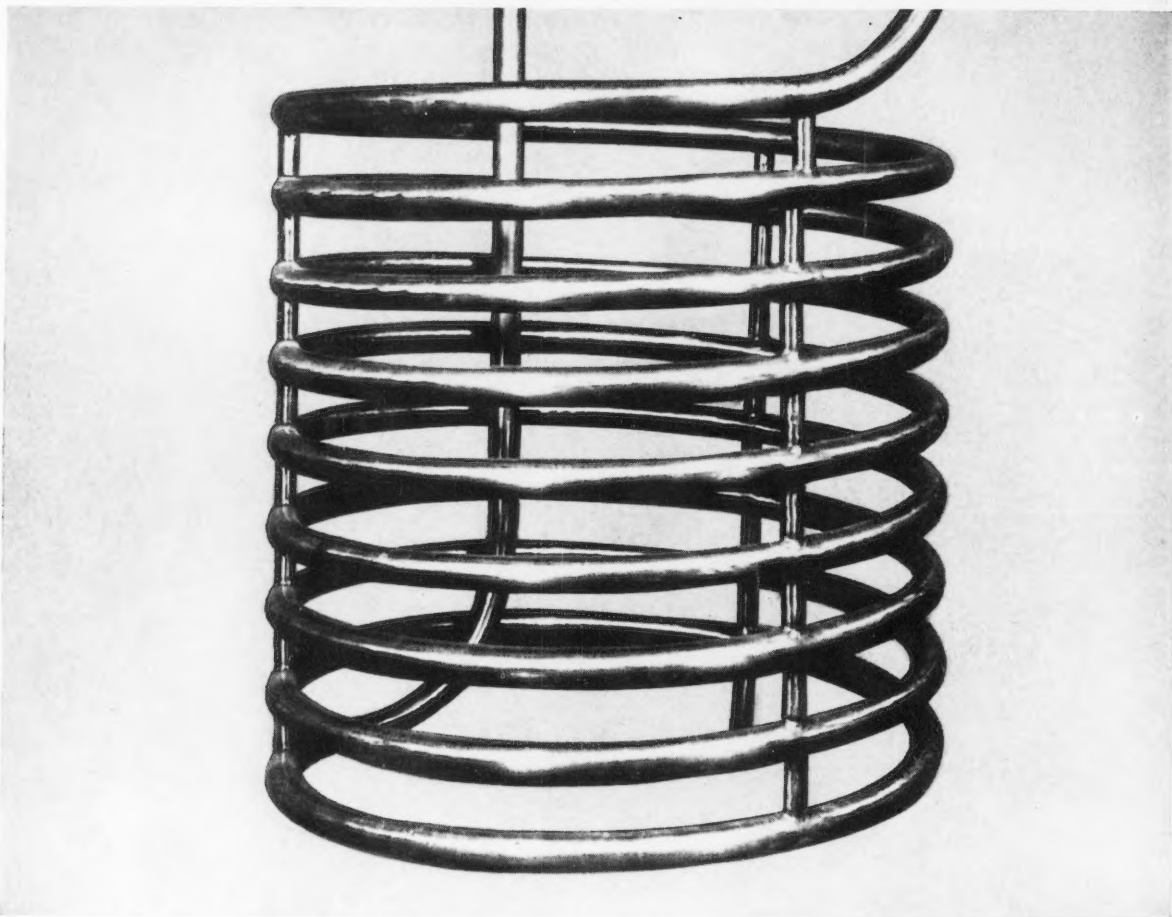
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This titanium heating coil is expected to give 5 years' trouble-free service handling a 12% sulfuric acid-bearing solution at atmospheric pressure.

**Titanium coil heats sulfuric acid solution
in presence of metallic sulfates**

- **LASTS 66% LONGER THAN SILVER**
- **CUTS OPERATING COSTS* BY 35%**

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Salt Water	Most Inorganic Chloride Solutions
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Nitric Acid	Chromic Acid
Wet Chlorine	Aqua Regia
Chlorinated Organic Compounds	Hypochlorites & Chlorine Dioxide

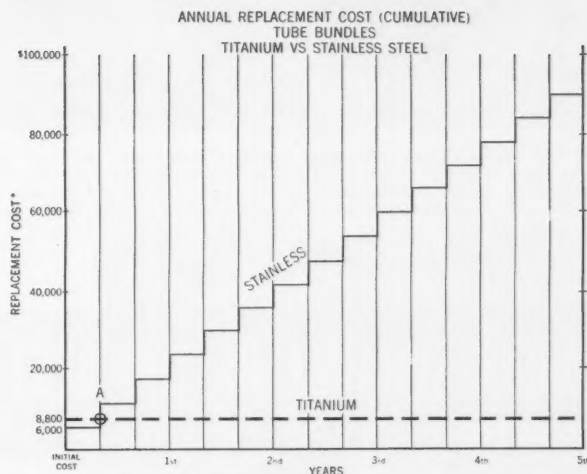
TITANIUM—available today

Titanium is now readily available for non-defense applications. Standard parts of titanium are already solving severe corrosion problems in the chemical, food, pulp, paper and allied industries.

In your process development work, take advantage of the corrosion and cavitation resistance, light weight and high strength of titanium...important considerations for continuous flow, high temperature and pressure processes.

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SOME OF THE INSTRUCTORS in the Basic Corrosion Short Course presented by the San Diego Section are shown. The four-session night classes started September 12. On the left, Norman Larsen lectures on Theories of Corrosion, in the center panel members John Steihl, left and Reuben Tullis, center are shown with Dan Nordstrom, panel moderator. On the right, Ken Christy describes results of a corrosion test on water heaters conducted by the City of San Diego, Corrosion Section.

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- THICK INSULATING LINER
- ANCHORED BY INSULATED CABLES

SIZES: 4" to 36"



NATIONAL and REGIONAL MEETINGS and SHORT COURSES

1958

Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California.

Oct. 5-8—Northeast Region, Somersee Hotel, Boston, Mass.

Oct. 15-17—North Central Region, Cincinnati, Ohio.

Oct. 20-24—South Central Region, New Orleans, Roosevelt Hotel.

1959

NACE Annual Conference, Sherman Hotel, Chicago, Illinois.

Oct. 12-15—South Central Region Meeting, Denver, Col.

SHORT COURSES 1957

December 9-13—Biennial Short Course on Cathodic Protection, University of Illinois and NACE.

SHORT COURSES 1958

January 23-24—Houston Section Short Course for Pipeliners, University of Houston.

Feb. 12-14—Ninth Annual Tulsa Corrosion Short Course for Pipeliners, Mayo Hotel, Tulsa, Okla.

E. R. SHEPARD

E. Raymond Shepard, a member of NACE from February, 1944, to April, 1954, a retired principal geophysicist in the office of the Chief of Engineers, United States Army, died October 17 at the age of 77. A graduate of Oregon State College, University of California and Harvard, he was inventor of a seismograph used in connection with the erection of dam structures. He was on the staff of the National Bureau of Standards for many years.

He worked on engineering studies for the St. Lawrence Seaway and the second lock facilities for the Panama Canal, besides many other large projects.

Following his retirement in 1950 he was associated with the Hinchman Corp., Detroit, doing considerable work on corrosion prevention for the Bureau of Yards and Docks on the Pacific Coast, in Alaska and in Washington, D. C., his home, for the National Capital Housing Authority.

He was author of numerous technical articles, including some published in CORROSION.

E. M. GRIFFIN

E. M. Griffin, an employee of Southern Bell Telephone and Telegraph Co. since 1924 died September 22 after a heart attack. He was vice-chairman of Birmingham Section and active in NACE affairs.

CORROSION published 137 articles and reports in its Technical Section during 1957.



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Versatile, reinforced LAMINAC Polyester Resin is solving several corrosion problems for MacMillan & Bloedel, one of Canada's major pulp and paper mills.

In the bleach pulp plant, for example, highly corrosive chlorine dioxide, sulphur dioxide, and chlorine are used in processing. Trouble with leakage plagued stainless steel sewer lines used to remove spent chemicals. Contamination by metal had developed in the conveyor screw handling bleached kraft stock from washer to storage.

Lined 20 months ago with glass-reinforced LAMINAC 4119, the conveyor screw, shown here, is holding up well, no longer contaminates. Now all sewer lines are being lined with LAMINAC, while lines in a new plant under construction are to be entirely fabricated of this material. MacMillan & Bloedel has fabricated a 3-foot reinforced LAMINAC radial exhaust fan, and is covering floors and ceramic and wooden exhaust stacks with reinforced LAMINAC.

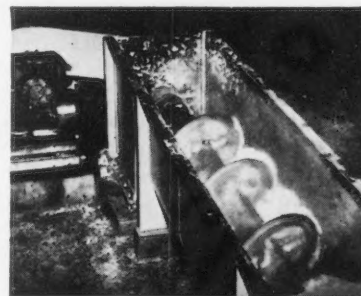
You may find reinforced LAMINAC equally versatile for handling corrosive materials, fluid and fumes. Talk with your Cyanamid representative about the many possibilities it offers for reducing maintenance and extending equipment life.



Fibrous glass cloth being applied to flight of conveyor screw which moves bleached kraft stock from washer to storage.



Finish coating of LAMINAC Resin is applied to conveyor screw with built-up coating of LAMINAC and glass cloth.



Conveyor in operation. Inside of trough, as well as screw, is lined with glass fabric-reinforced LAMINAC Resin.

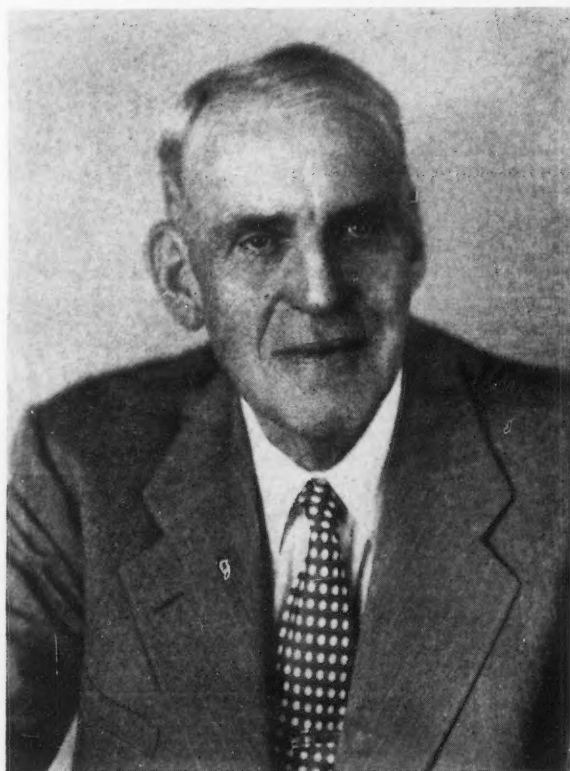


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In Memoriam Starr Thayer

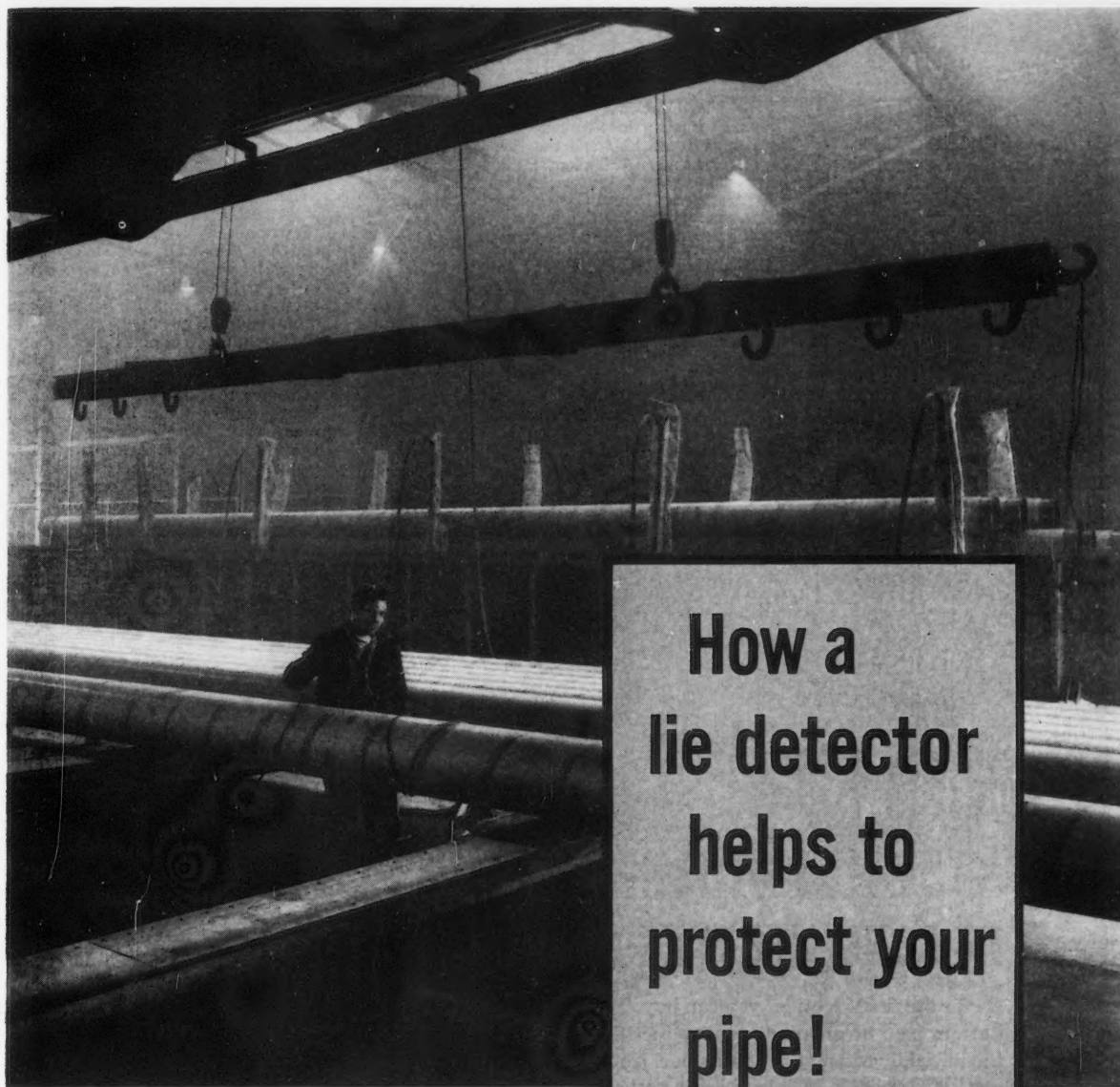
OUR FRIEND, Starr Thayer, died on October 29, 1957, after a relatively short illness. Starr was a pioneer among those who take a positive approach in the control of corrosion, but he will probably always be best remembered as a friend, generous with his time and helpful knowledge, to all who sought his counsel.

Starr was one of the first in the Mid-Continent Area to apply cathodic protection to the control of pipe line corrosion, and he made significant contributions to the development of specialized equipment, instrumentation and procedures in this field. Early in his activities he recognized the need for cooperation among engineers, owners of underground facilities, scientists and others interested in this activity. Characteristically he did something about it by taking a leading part in the formation of the cooperative groups which later developed into the National Association of Corrosion Engineers.

From the first and consistently through the

years, Starr Thayer demonstrated that many types of corrosion could be controlled effectively by cathodic protection. He was always helpful and encouraging to others, published many articles and reports, and gave freely of his information and advice. This aid to an entire industry in lowering its maintenance and operating costs and in conserving the nation's transportation facilities was engineering achievement of the finest sort. It was, therefore, with special pride that his friends saw him receive the Frank Newman Speller Award for Corrosion Engineering Achievement from the National Association of Corrosion Engineers during its Eighth Annual Conference at Galveston in 1952.

Starr's friends will never forget his thoughtfulness and kindness, and corrosion engineers and those who benefit from their service will forever owe a great debt of gratitude to this pioneer who helped so much to establish the corrosion engineering profession.



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Have You Noted The Technical Topics Section?

In every issue of **CORROSION** a "Technical Topics" section is published. It includes timely technical information likely to interest you. Turn to Page 127 this issue.

CORROSION is indexed annually in December with an alphabetical subject, alphabetical author index and collected contents of the Technical Section and an annual subject index to the Corrosion Abstract Section.

Permanent Officers Named For Panhandle Section

The election of permanent officers for the Panhandle Section to serve the remainder of 1957 and the year 1958 are as follows: W. A. Tinker, Phillips Petroleum Company, chairman; Robert E. Allen, Northern Natural Gas Company vice-chairman; James W. Edminston, Cabot Carbon Company, secretary-treasurer; and Jack R. St. Clair, Dearborn Chemical Company, trustee.

The 1957 alphabetical subject index to **CORROSION**'s Technical Section occupies four pages.



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SECTION CALENDAR

Dec.

- 3 Shreveport Section. Washington-Youree Hotel, Shreveport.
- 11 Metropolitan New York Section. Chi-Am Chateau, Westfield, N.J. Special Christmas Meeting. NACE corporate memberships; W. H. Stewart, Sun Pipe Line Co., Beaumont, special guest.
- 17 Philadelphia Section. Poor Richard Club, M. G. Fontana, Ohio State University, Columbus: Various Approaches to Corrosion Problems.
- 17 Southwestern Ohio Section. Christmas Party.
- 17 Cleveland Section. Anton de S Brannas, American Society for Metals.
- 30 New Orleans-Baton Rouge Section. Engineers Club, DeSoto Hotel, New Orleans.

Jan.

- 7 Shreveport Section. Washington-Youree Hotel.
- 21 Cleveland Section. Joint meeting with The Electrochemical Society. F. L. LaQue, The International Nickel Co., Inc.
- 21 Chicago Section. Use of Inhibitors in the Oil and Chemical Industries.
- 27 New Orleans-Baton Rouge Section. Engineers Club, De Soto Hotel.
- 28 Southwestern Ohio Section. Underground Corrosion, Sponsored by Cincinnati Gas & Electric Co.

TEXAS UNIVERSITY PLANS PIPELINE CORROSION FILMS

Three films on pipeline corrosion are being prepared by the Petroleum Extension Department of the University of Texas, Austin. They are being financed jointly by funds of the university and from contributions solicited from industry by the University of Texas. The films planned are: Fundamentals of Pipe Line Corrosion, 10 minutes; Pipe Line Coatings, 15 minutes and Cathodic Protection, 15 minutes.

The educational films are designed to aid in educational programs for operating field personnel and others without technical corrosion engineering training. Copies will be available at a price to be fixed by the university.

R. A. Brannon, Humble Pipe Line Co., Houston is chairman of a committee of the National Association of Corrosion Engineers appointed to give technical advice. Outlines for the three films have been approved by the committee and it is expected to review the preliminary scripts of the first film in the near future.

The 1957 alphabetical subject index to **CORROSION**'s Technical Section occupies four pages.

With this new round shape, UNITRACE costs substantially less per foot. And since the steam passage has less outside wall area, external radiation heat loss is reduced. The need for thermal insulation is often eliminated. When insulation is used, it costs less because standard pre-formed pipe covering can be used.

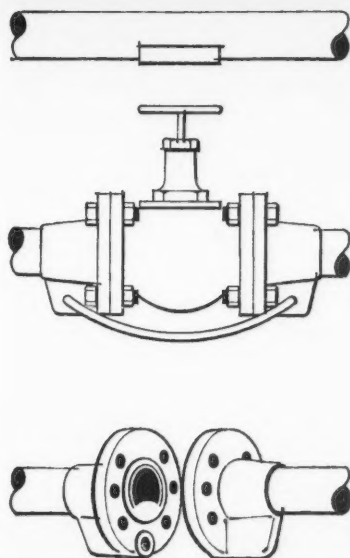
ALCOA UNITRACE has a NEW SHAPE

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easier joining...

*less heat loss...better
internal heat transfer*



Sections of UNITRACE in the new shape can be easily and quickly joined by the weld and patch method (top). And a brand new UNITRACE flange—with product and steam passages cast as integral parts of the flange—simplifies installation of valves (center) and other flanged connections (bottom).

Want to save money on steam-traced piping? Here's good news for your pocketbook! ALCOA® UNITRACE has a new cost-cutting shape . . . a round section matching standard pipe shapes . . . available in 1½", 2", 3" and 4" sizes.

With steam and product passages extruded in a single unit of light, strong, corrosion-resistant Alcoa aluminum alloy 3003-F, UNITRACE completely eliminates the cost of external steam jackets or tracer tubes. And the new UNITRACE shape makes possible these extra savings:

Lower cost per foot . . . total volume of metal is less; material costs are lower.

Easier, faster joining . . . new configuration (with exterior grooves for quick steam passage identification)

makes mating and joining fast and simple to cut installation costs.

Less external heat loss . . . improved internal heat transfer . . . the new design reduces area for external radiation loss.

The natural corrosion resistance of aluminum makes UNITRACE ideal for handling naval stores, molten sulfur, ammonium nitrate solutions, glacial acetic acid, fatty acids, tar, pitch, wax, urea and similar products which normally require heated transfer lines.

Find out today how you can use ALCOA UNITRACE to cut costs and improve efficiency of your heated transfer lines. Call your nearest Alcoa sales office, or write Aluminum Company of America, 892-M Alcoa Building, Pittsburgh 19, Pennsylvania.



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12-Paper Chemical Industry Symposium Filled

Business and Pleasure Combine Readily for Visitor to San Francisco and West Coast

The visitor to the West Coast and San Francisco in particular finds it easy to combine business with pleasure. San Francisco, scene of the 14th Annual Conference and Exhibition of the National Association of Corrosion Engineers, is a commercial center of major importance, being the home of 30 large corporations with combined assets exceeding \$32 billions and hundreds of smaller businesses of all kinds.

Coincident with the rapidly growing population of the West Coast, industrial expansion and diversification has been spectacular ever since the mushroom growth brought about by World War II. Firms include large electric and gas companies, banks, railroad systems, steamship companies, petroleum processing, chemical manufacturing, heavy industries of all kinds, including steel, lumber, shipbuilding, aircraft, canning, brewing, sugar refining and others.

D. R. Loper, general chairman for the conference urges NACE members to consider first of all the splendid technical program that has been arranged and then to consider whether attendance at the NACE conference cannot be combined profitably with other business activities.

Mr. Loper pointed out that applications for housing space have been mailed to NACE members already, an advance program is in the mails and additional copies of hotel space reservations and programs can be secured from Central Office NACE on request.

The bustling cities from Portland to San Diego, including San Francisco and Los Angeles offer numerous opportunities for fruitful business contacts, Mr. Loper says.

Cunningham Is Named

Ralph M. Cunningham, Birmingham, Alabama has been appointed secretary-treasurer of Birmingham Section.

Twelve More Firms Get Space In Exhibition

Eleven more firms have reserved space in the 14th Annual Exhibition of the National Association of Corrosion Engineers to be held in Civic Auditorium, San Francisco March 18-20 concurrently with the 14th Annual NACE Conference. These are in addition to firms whose names were published in Corrosion in October on Page 112 and in November on Page 126.

About 75 percent of the booths available have been reserved.

Eleven additional firms that will participate are:

Alloy Steel Products Company, Linden, New Jersey
American Smelting & Refining Company, New York, N.Y.
Crane Company, Chicago, Ill.
The Dow Chemical Company, Saran Lined Pipe Dept., Midland, Mich.
Fabri Valve Company of America, Portland, Ore.
General American Transportation Corp., Compton, Cal.
The Glidden Company, Cleveland, Ohio
Koppers Company, Pittsburgh, Pa.
Lukens Steel Company, Coatesville, Pa.
Minnesota Mining & Mfg. Co., Minneapolis, Minn.
Pittsburgh Coke & Chemical Company, Pittsburgh, Pa.
The Spee-Flo Company, Houston, Texas

SAN FRANCISCO'S EMBARCADERO is prominent in the foreground of this spectacular aerial view. This photograph of the city's magnificent harbor shows why it is one of the principal ports for goods to and from the Orient and why it is so important as a commercial center. Also shown in the photograph are the suspension half of the San Francisco-Oakland Bay bridge connecting in the right foreground with Yerba Buena island. Tiny island between Yerba Buena and Marin County is the Alcatraz Federal Penitentiary. The Golden Gate Bridge is shown in the distance.



Atomic Reactors, High Energy Fuels To Get Attention

A twelve-paper chemical industry symposium has been divided into three sessions for the 14th Annual Conference and Exhibition of NACE to be held in San Francisco March 17-21. Significant among the papers are five related to atomic reactors and high energy fuels for rockets.

The symposium is one of 16 symposia to be presented. In addition to the symposia three educational lectures are planned and two round tables will be held. This array of technical sections makes the meeting by far the largest so far arranged by the National Association of Corrosion Engineers. So far a total of 84 papers has been scheduled.

In addition to these technical meetings arrangements have been made for sessions of more than 70 technical committees. In contrast to previous national conferences Monday March 17, first day of the meeting, will include triple simultaneous symposia during the afternoon. Formerly Monday has been devoted solely to technical committee meetings.

Scheduled papers to be presented during the Chemical Industry Symposium are:

Corrosion in the Production and Handling of Fertilizer Chemicals, H. O. Teeple, The International Nickel Co., Inc., New York.

Materials of Construction for Hydrofluoric Acid Service, F. W. Fink, Battelle Memorial Institute, Columbus, Ohio.

Lead-Acid Brick Construction, E. J. Mullarkey, Lead Industries Association, New York, N. Y.

A New Inorganic Cement Mortar for Sulfuric Acid Service, R. S. Mercer, Pennsalt Chemicals Corp., Philadelphia, Pa.

Control of Corrosion in Nitric Acid Solutions by C. L. Patterson and F. W. Fink, Battelle Memorial Institute, Columbus.

Engineering Use of Sodium as a Heat Transfer Agent and Its Corrosive Effect by W. D. Manly, Oak Ridge National Laboratory, Union Carbide Nuclear Corp., Oak Ridge, Tenn.

A Resume of Corrosion Characteristics of Structural Alloys in Various Coolants, W. D. Manly.

Handling Hydrogen Peroxide for Missile Service, R. Bloom.

Corrosion Problems in Uranium Refining, F. H. Meyer.

Zirconium, H. A. Anderson, Carborundum Metals Co., Inc., Akron, New York.

Titanium Equipment and Corrosion Economics, G. T. Bedford.

Stress Corrosion of a Stainless Steel in Dowtherm, D. K. Priest, Pfaudler Co., Rochester, N. Y.

Miller Is Northeast Region 1958 Meeting Chairman

Harvey S. Miller, New England Hard Facing Co., Inc., Brookline, Mass. is chairman of the Northeast Region 1958 meeting to be held in Boston, October 5-8, 1958.

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Progress Made During 1957 By Corrosion Is Reported

Considerable progress was made during 1957 in increased volume of technical material in CORROSION's Technical Section and by addition of a new section of the magazine devoted to technical materials called "Technical Topics." A gain of 190 pages, or 30 percent was made in Technical Section pages alone over the number published during 1956. If the additional 33 pages published in the Technical Topics Section is added to this number of additional pages of technical material is 223 or 34 percent more than was published last year.

This increase is reflected in part by the more than 25 percent increase in space occupied by the Alphabetical Sub-

jects, however, in the index. As usual an index is published of the Corrosion Abstract section for those readers of CORROSION who bind this section separately.

The index to the volume has not been included in the pagination of the issue so it may be extracted and bound with the collected Technical Sections. The usual page of errata is published. All is done according to the recommendations of the American Standards Association.

Technical Section	1956	1957	Diff.
Articles	105	137	+32
Authors	185	244	+59
Discussions	62	140	+78
Pages	652	842	+190

Philadelphia Panel Has Audience of Over 100

A panel discussion on materials of construction attracted 64 members and 41 guests to the October 29 meeting of Philadelphia Section at the Poor Richard Club. A lively discussion triggered by questions from the floor followed the panel's presentations.

Norman D. Groves, Carpenter Steel Co., was moderator and panel members and their subjects were: W. B. DeLong, E. I. duPont de Nemours & Co., Inc., metallic materials; K. P. Chamberlain, Industrial Plastics Fabrication, Inc., plastics and R. R. Pierce, Pennsalt Chemicals, Inc., ceramics, ceramic coatings and masonry materials.

Names of nominees for 1958 offices were announced. Voting will take place at the December 17 meeting at which Mars G. Fontana, Ohio State University, Columbus will be principal speaker.



PHILADELPHIA PANEL members were, left to right: R. R. Pierce, Pennsalt Chemicals, Inc.; W. B. DeLong, E. I. duPont de Nemours & Co., Inc.; Norman D. Groves, Carpenter Steel Co., moderator; K. P. Chamberlain, Carico Corp.

Additional Indexing

Beginning with the issue of January, 1958 CORROSION will be indexed regularly by Applied Science and Technology Index. This is in addition to the regular indexing of Engineering Index.

ject Index to Volume 13, included in this issue immediately following the Technical Section. Also indicative of the increased volume are the 140 discussions and 244 authors, both substantially more than those recorded in 1956.

The subject index does not include articles published in the Technical Topics section because they are not numbered in the Technical Section "t" number sequence. Their collected contents ap-

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GREAT BEND, KANSAS. Harvey Fanshier, Mid-Western representative for Corrosion Rectifying Company is a graduate of Kansas State College with extensive experience in salt water disposal and corrosion prevention. Rt. 2, Great Bend, Kansas.



NEW ORLEANS, LA. James T. Condry, New Orleans representative, is a graduate Electrical Engineer in charge of evaluation, design, installation and materials sales for the Louisiana territory. He has wide experience in marine and offshore installations. 2322 Airline Highway, Kenner, Louisiana.

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Corrosion & Chemical Sales Engineer, presently employed in sales and service of industrial, municipal and federal accounts, desirous of change. CORROSION, Box 57-21.

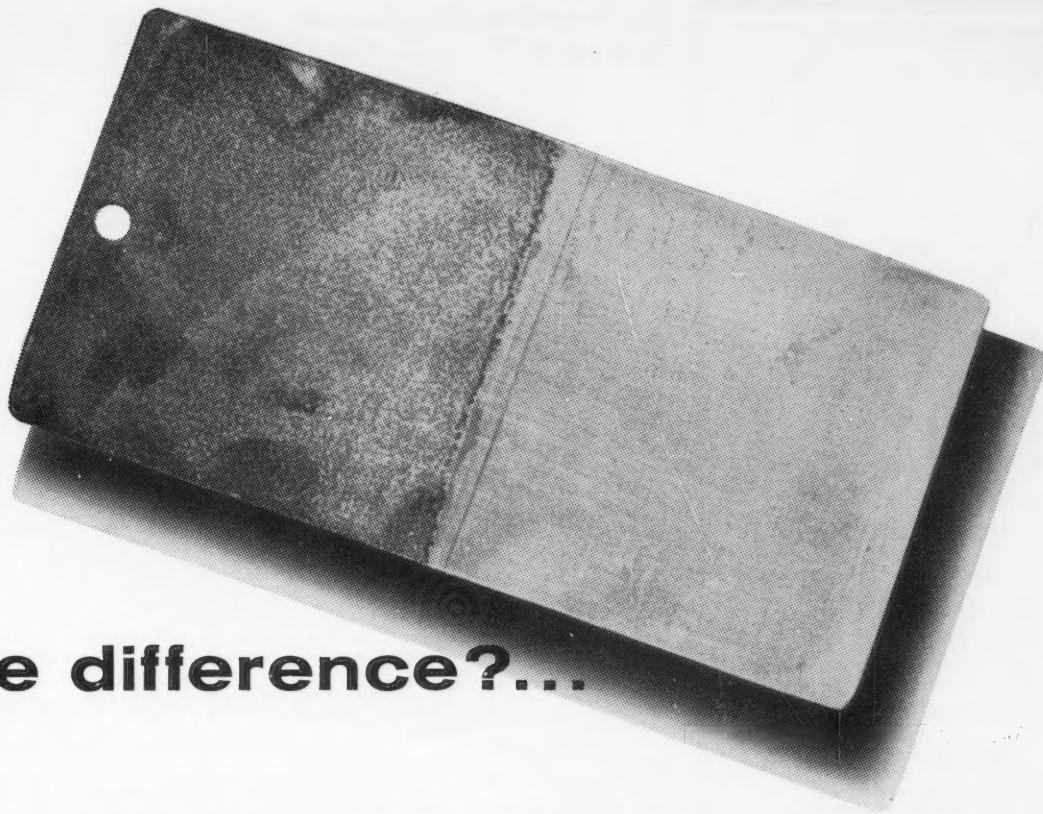
Aggressive Young Man with seven years experience in industrial paint formulation and three years practical applications problems in organic corrosion resistant coatings, interested in technical, management, or tech service position. Reply CORROSION, Box 57-23.

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Southwestern Ohio Section Will Hold Christmas Party

Southwestern Ohio Section will hold its Christmas party December 17.

Scheduled for the November meeting was an illustrated talk on Corrosion Problems in Distillery Operations, by John A. Frank. Arrangements were made to hold the meeting at the Top O' The Ridge restaurant, Cincinnati with the fellowship hour sponsored by the National Distillers Products Corp., the firm with which Mr. Frank is associated.

The section acted in support of NACE on two major objectives in its October 29 meeting also held at Top O' The Ridge restaurant. To promote attendance at the NACE 14th Annual Conference and 1958 Exhibition, Section Chairman Sol M. Gleser, A. M. Kinney, Inc., Cincinnati distributed posters for posting on company bulletin boards advertising the conference. The drive for corporate members was aided by description and display of a brochure designed to sell corporate memberships in NACE.

Regional Meeting Studied

To aid in planning the 1958 North Central Region meeting to be held in Cincinnati, three members reported on a study made of the October 1957 meeting held in Chicago. The members were: W. E. Hare, Hare Equipment Co.; Sylvan Falck, and L. M. Lederer, both of Inner-Tank Lining Corp. Mr. Hare reported on general aspects of the convention. He stated that much was learned in planning for the 1958 meeting. He also has arranged to attend the Northeast Region meeting in November. Mr. Falck reported that the technical program for the North Central 1957 meeting in Chicago was well organized and well presented. Mr. Lederer said he learned much on organization, planning, publicity and finance.

Zinc Paint Tests Described

J. Teres, chief, Protective Processes Branch, Materials Laboratory, Air Research and Development Command, U. S. Air Force, Dayton, Ohio was the technical speaker at the October meeting. His illustrated lecture was on Conductivity Testing of Zinc Dust Pigmented Coatings. He said properly formulated zinc pigmented coatings give protection for steel through cathodic action. Coatings must be good conductors of electrical currents.

The development of various tests to measure electrical resistivity of coatings was described. A glass panel, about 3 by 5 inches coated on one side and with two square sheets of aluminum foil covering the coating except for a one-quarter inch gap at the center of the panel gave reproducible resistance values of the coating in the gap between the sheets of aluminum foil serving as contact electrodes to the coating under test.

Coating Resistance Formula

It was determined that the resistance values of properly formulated zinc dust pigmented coatings followed a mathematical relationship stated in words as follows: The measured resistance is proportional to rho times the width of the gap or slot all divided by the length of the slot times the thickness of the coating.

It was found that rho, the specific resistance of the coating, was not only dependent on the formulation of the coating: i.e. on the concentration of the

zinc dust and the nature of the vehicle, but also was a function of the thickness of the coating.

From tests made with various thicknesses of coatings, it was learned that at a thickness of 14 mils the coating in the slot acted as a solid metal conductor and is, therefore, the optimum thickness for the test procedure. It is to be recognized that the 14-mil thickness is not necessarily the optimum thickness, everything considered, for coatings to be applied to protect steel.

Variations in the measured resistance with concentration of zinc dust and with drying time of the vehicle were described and discussed from a theoretical viewpoint.

Test Is Demonstrated

Mr. Teres demonstrated the test procedures on several sample panels using an ohmmeter to read directly the resistance values.

A lively and diversified discussion, comments and questions and answers followed the talk. Characteristics of various vehicles as related to the test procedure and their proved effectiveness were pointed out. It was also brought out that the test was of value in arriving at the best concentration of the zinc dust pigments and at the proportions of metallic zinc to oxides of zinc and other metals.

Down Hole Corrosion in East Texas Field Reviewed

At East Texas Section's meeting, Harry G. Byars, Atlantic Refining Co. spoke on Corrosion in the East Texas Field. Mr. Byars reviewed the findings of T-1C-5, East Texas Task Group of which he is chairman, which studied down-hole corrosion in the East Texas Field. Sixteen members and 34 guests attended.

Corrosion in the field is classified as mild to severe depending on local conditions such as large water production and other factors. The general practice is to flush chemical inhibitors down the casing, Mr. Byars said.

From an economical standpoint, operators estimate that the protection of rods, tubing and pumps has reduced expense for repair and replacement of such equipment by 75 to 90 percent.

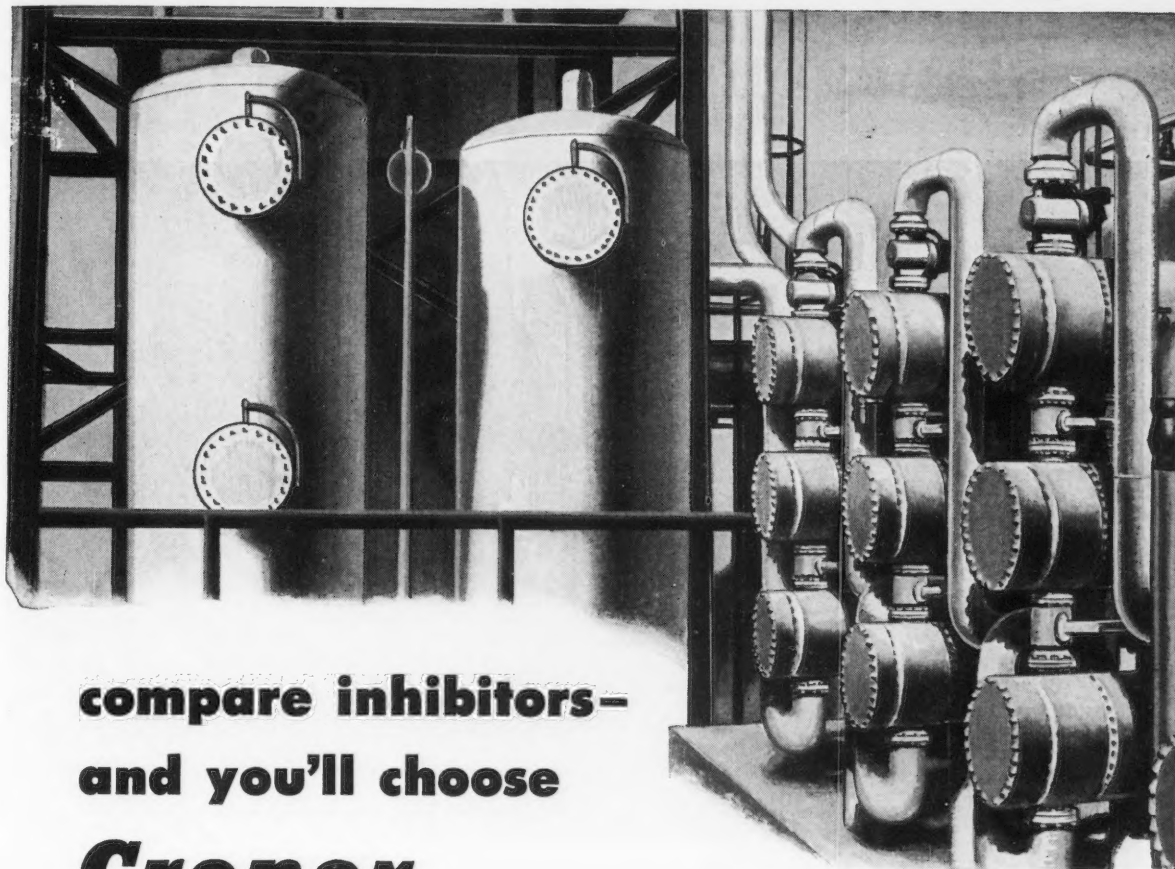
Election of officers for 1958 was scheduled for the November 26 meeting in Longview, Tex. A nominating committee presented a suggested list of officers at the October 22 meeting.

Super High Pressure Well Corrosion Topic at Dallas

Corrosion and equipment problems involved in the operation of super high pressure gas wells was the subject of discussion at a meeting of the North Texas Section held Nov. 4 in Dallas. M. J. Epperson covered the mechanical phases of the topic and D. R. Fincher gave a report on the chemical aspects of treatment.

The relative merits and experience with double, double concentric and single tubing strings were discussed along with various tubing materials and methods of injecting inhibitors.

The program was designed to be of interest to both corrosion and non-corrosion engineers. Twenty-two members and twenty-six guests attended.



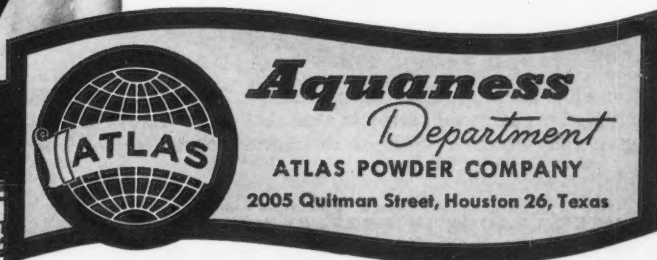
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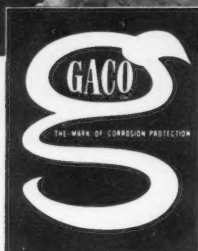
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Chemicals for Refining, Gasoline Plants and Oil Transportation

Management says YES



These are the men who are concerned with corrosion at Washington Steel Products, Inc., of Tacoma, Washington. Left to right: R. H. (Dick) Christopherson, Foreman of Maintenance. Sidney M. Collier, Vice-President, Gaco Western, Inc. K. W. (Ken) Smith, Works Manager. T. O. (Tom) Presleigh, Foreman, Plating Dept.

GACO Neoprene Protective Coatings solve another tough one...

Beating Corrosion is a man-sized job. Take Washington Steel Products, Inc., manufacturers and platers of the most complete line of cabinet hardware and cabinet accessories in America. Coatings on the chromic acid wash tanks at the end of the electroplating line, adjoining ventilating system, framework and concrete floor were lasting only three months . . . and coating four times a year is costly. Enter GACO Neoprene Protective Coatings. Result? Let management speak for itself—

SID COLLIER: *Ken, what's been your experience with GACO Protective Coatings?*
GACO Representative

KEN SMITH: *Results count here in a big way, and Dick and Tom here are the people who have the responsibility to either approve or disapprove your GACO Protective Coatings. Tom, what does Plating have to say about GACO Protective Coatings?*

TOM PRESLEIGH: *Corrosion is my big headache. So far GACO N-700 and N-200 have been the most satisfactory coatings I have ever used for resisting corrosion.*
Foreman, Plating Dept.

KEN SMITH: *Dick, how about Maintenance? What's been your experience with GACO Protective Coatings?*

DICK CHRISTOPHERSON: *We've got a good product there. It's easy to apply and stands up better than anything we've used before.*
Foreman of Maintenance

Let the big **G** do for you what it did for the men in Tacoma. There's an entire family of GACO heavy-duty corrosion-protection products and services available and a GACO Corrosion Specialist in your area prepared to serve your needs. For complete information write—we'll forward literature of interest.

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GENERAL NEWS



SEAHORSE INSTITUTE'S WILLIAM F. CLAPP Memorial Award is being presented here to Carroll M. Wakeman, Los Angeles during last summer's meeting of the Institute at Harbor Island, N. C. F. L. LaQue, manager of the International Nickel Co., Inc., Development and Research Div., (left) is shown with Mr. Wakeman, chairman of NACE's T-8 committee on Marine Biological Deterioration. Mr. Wakeman has been a leader in marine borer research in Southern California for 20 years and has been prominent in activities of the Southern California Marine Borer Council.

Polish International Corrosion Convention Attracts 350 to Gdansk September 19-21

Some 350 scientists and engineers attended the First International Corrosion Convention at Gdansk, Poland September 19-21 under auspices of the General Scientific Federation of Poland. Emphasis of the convention was on marine corrosion. Some 20 papers were presented covering pure science and most aspects of combatting marine corrosion.

K. A. Spencer, of Spencer and Partners, corrosion consultants, London, a member of the National Association of Corrosion Engineers was the sole representative of the Western world at the meeting. Mr. Spencer reported a keen interest in corrosion prevention in Poland and that his paper "Cathodic Protection of Ships and Marine Structures," and the International Nickel Co., Inc. film "Corrosion in Action," were well received.

Chairman of the session was Prof. M. Smialowski. Papers were given by Polish, Yugoslav, Czech, Egyptian, German and Russian scientists, including Prof. H. D. Tomaszow and Prof. V. A. Pritula of Russia and Prof. F. Erdmann-Josnitzer of Germany.



POLAND'S FIRST INTERNATIONAL Corrosion Convention at Gdansk September 19-21 was the scene of the photograph above. Left to right are: K. A. Spencer, Spencer and Partners, Consultants, London, England and Prof. M. Smialowski and Dr. R. Juchiewicz, respectively chairman and secretary of the convention.

NACE's 14th Annual Conference and Exhibition will be held in San Francisco.

South Central Region NACE meets in New Orleans in 1958.

BOOK NEWS

A Symposium on Internal Combustion Engine Valves. 216 pages, 8 x 10½ inches. July, 1957. Valve Division, Thompson Products, Inc., Cleveland, Ohio. Availability not indicated.

Principal interest of corrosion workers in this volume is in the article "Laboratory Testing Techniques" by M. J. Tauschek and J. C. Sawyer, Thompson Products, Inc. This paper was presented at a November 15-16 meeting of North Central Region National Association of Corrosion Engineers at Detroit, Mich. Another paper by the same authors is reprinted from CORROSION's January 1956 issue, "Corrosion of Gasoline Engine Exhaust Valve Steels." The other articles by Thompson workers are on other aspects of the engine valve including engineering, burning and sticking, design and others.

The North Central Region NACE paper discusses laboratory testing of steels in corrosives encountered in gasoline engines and correlation with experience testing.

Selection and Application of Metallic Rectifiers. By Stuart P. Jackson. 1957. 326 pages, 6 x 9, cloth. The McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 36, N. Y. Per copy, \$8. The book is designed to present reference information useful in application of metallic rectifiers. Sections are devoted to application, circuits, complex loads and filters, selection of correct type, copper-oxide, selenium, magnesium-copper, germanium and silicon rectifiers; condensed theory of junction rectifiers, application of theories to rectifiers, battery charging, electroplating supplies, industrial power supplies, application; magnetic amplifiers, special purpose circuits and definitions.

The book is profusely illustrated with diagrammed data, contains numerous tables and formulas, bibliography and index.

Concrete Deterioration of a Foundation. 48 pages, 6¼ by 9¾ inches, paper. By G. M. Idorn. 1957. Acta Polytechnica No. 221. Acta Polytechnica Publishing Office, Box 5073, Stockholm 5, Sweden. Per Copy, Sw. kr. 8.00.

This monograph describes deterioration of a concrete foundation for a silo in the harbor of Copenhagen. The foundation was poured with concrete of an unknown composition about 50 years ago.

Details are given of the ground water composition, soil characteristics, petrographic examination, and physical characteristics of the concrete, badly disintegrated below the ground water level. Carbon dioxide is credited with the major destruction, assisted by sulfates.

The monograph concludes that some consideration needs to be given to concrete poured below water levels, with

(Continued on Page 116)

BOOK NEWS

(Continued From Page 115)

special emphasis on care where aggressive carbon dioxide constituents are present in ground water. Some remedial and preventive suggestions are given.

Epoxy Resins—Their Application and Technology. By Harry Lee and Khristine. 305 pages, 6 x 9 inches, cloth. 1957. The McGraw-Hill Book Company, Inc., 330 West 42nd St., New York 36, N. Y. Per copy, \$8.00.

A comprehensive review of information on the epoxies. Extensive tabulated and diagrammed data are given on synthesis and characteristics, curing; amines, amides, organic acids, anhydrides as curing agents; diluents and fillers, plasticizers, and flexibilizers, casting and potting, adhesives, laminates, coatings, handling methods and safety precautions. An alphabetical chemical index is included.

European Federation of Corrosion Meets May 31

European Federation of Corrosion's May 31-June 8 congress at Frankfurt am Main, Germany will have as a theme "Corrosion and Chemistry." Sessions are contemplated on types and causes of corrosion of metals, non-metals; protection against corrosion, methods of test, planning and rationalization.

NACE now has 54 sections.

Air and Water Pollution Control Are on Agenda

Prevention of air and water pollution are to be considered during the January 27-30 Chicago Plant Maintenance Conference.

General sessions have been scheduled on: Getting Management Support for Maintenance, Fundamentals of Preventive Maintenance, Fundamentals of Planning and Scheduling, Fundamentals of Maintenance Cost Control and Prevention of Air and Water Pollution. The pollution session will cover in-plant and exterior pollution problems.

NEW PERIODICALS

Platinum Metals Review. Quarterly, 7 1/4 x 10 inches. Johnson, Matthey & Co., Ltd., Rustenburg, S. Africa. Editorial offices, Johnson, Matthey & Co., Ltd., Hatton Garden, London, E.C.1.

This publication's October, 1957, issue, No. 4 of Vol. 1 contains an alphabetical subject index to Vol. 1. Articles are included on liquid steel temperature measurement, total synthesis of vitamins, creep testing of platinum alloys, extraction and purification of plutonium metal, platinum alloy permanent magnets, among others.

A section is devoted to abstracts. A forenote indicates the interest of the publication includes palladium, rhodium, iridium, osmium and ruthenium.

No indication of distribution policy is

included, but it is stated that copies are available from offices of the company.

Journal of the Joint Panel on Nuclear Marine Propulsion. Biannual. Publisher, The Institute of Marine Engineers, 58 Minorities, London, E.C. 3. This publication's April, 1957 issue is No. 1. A second issue for 1957 is scheduled to be published as of October. The joint panel is a function of the Institute of Marine Engineers, Institution of Naval Architects, Institution of Engineers and Shipbuilders in Scotland and North East Coast Institution of Engineers and Shipbuilders.

The purpose of the panel is stimulation and presentation of information on nuclear power applied to marine propulsion. Included in the first issue is a glossary of terms used in nuclear physics, description of types of reactors, and an article on safety.

Physics of Metals and Metallurgy and Journal of Abstracts—Metallurgy. English Editions of Russian journals of same titles. Acta Metallurgica, Pergamon Press, Inc., 122 E. 55th St., New York, N. Y.

Translations by the Pergamon Institute will be published of these journals which contain exclusive reports of scientific work in the Union of Socialist Soviet Republics and Iron Curtain countries through a grant made by National Science Foundation. The editions will total about 1500 pages annually.

ASME Schedules Over 250 Papers at New York

More than 250 technical papers were scheduled for presentation during the December 1-6 meeting of American Society of Mechanical Engineers at New York.

Included among the sessions were those devoted to air pollution controls, American Rocket Society, nuclear engineering, applied mechanics, aviation, boiler feedwater, furnace performance factors—corrosion and deposits, petroleum, power, process industries, steam, railroads, rubber and plastics, solar energy and wood industries.



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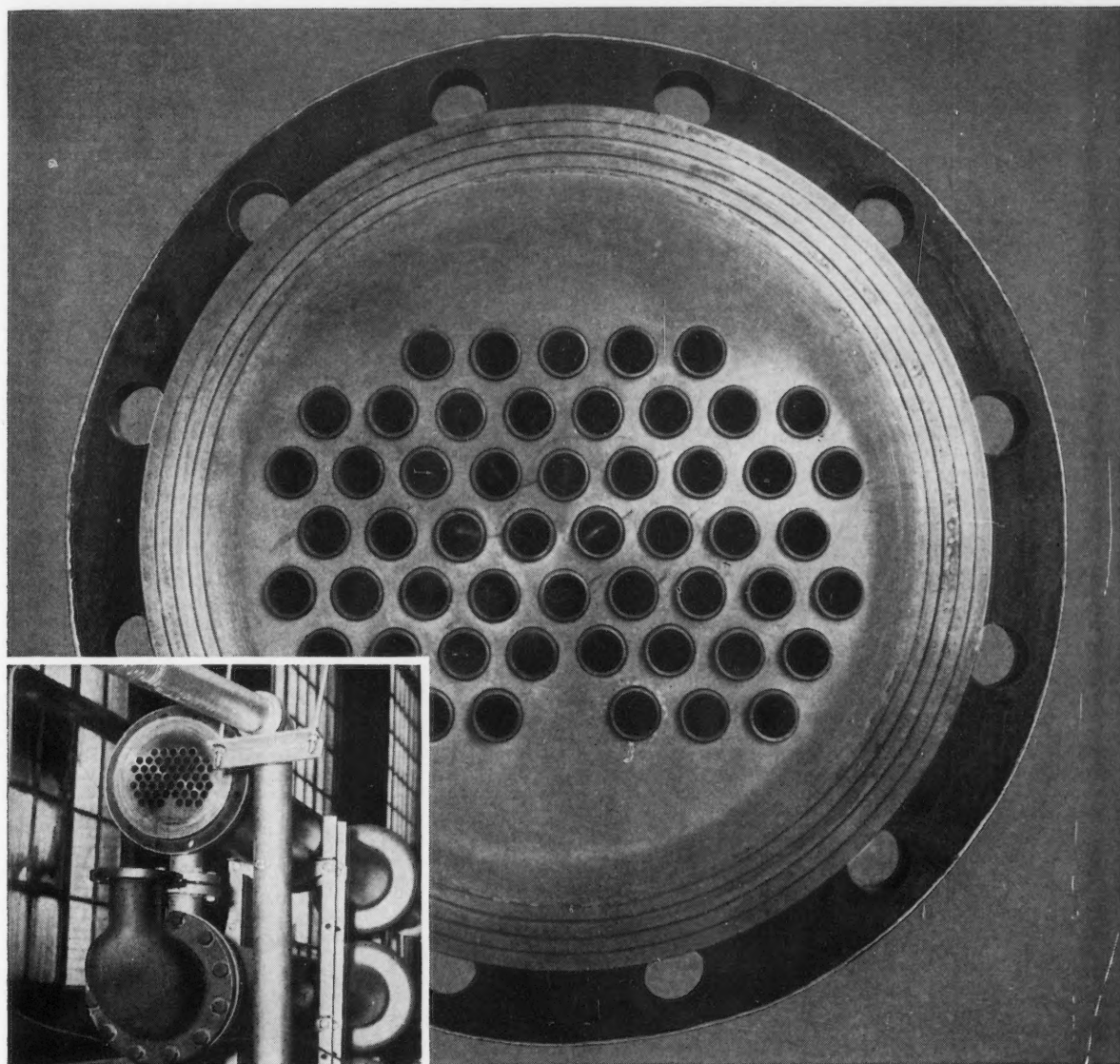
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NATIONAL ASSOCIATION of CORROSION ENGINEERS
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HOW CORROSION IS INDEXED

1. Alphabetical subject and author indexes are published in December at the end of the calendar year volume of 12 issues.
2. Abstracts of articles appear in the Corrosion Abstracts section of CORROSION.
3. Abstracts of articles appear in the NACE Bibliographic Surveys of Corrosion.
4. Abstracts of articles appear in the Corrosion Abstract Punch Card Service.
5. CORROSION is Indexed regularly by Engineering Index.
6. CORROSION will be indexed, beginning in January 1958 by Applied Science and Technology Index.
7. A 10-year alphabetical subject and author index (1945-54) has been published and is available for sale.



Carpenter 7Mo Stainless Tubing

No corrosion . . . no pitting after 4 years of handling hot SO₂ gases and vapors

• The smooth, clean surfaces of the Carpenter 7Mo Stainless tubing in this 3-pass Relief Gas Cooler tell the whole story. Still like new after 4 years of carrying 8% SO₂ gases and vapors from the top of a sulphite digester at temperatures in excess of 200°F. No maintenance. No replacement worries. No costly downtime.

If you have a tough corrosion problem involving stress corrosion cracking and pitting, see what Carpenter 7Mo Stainless Tubing and Pipe can do to solve it for good. Call your Carpenter Distributor for service that satisfies.

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Carpenter



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Equipment Services

NEW PRODUCTS

Materials Literature

Adhesives

Intertectics, Incorporated, Northfield and Forbes Rds., Bedford, Ohio, announces a new joining material and a new industrial technique for the chemical union of similar and dissimilar non-ferrous metals. The joint is frequently greater in corrosion resistance, usually stronger than either of the metals involved and has similar electrical, physical and chemical properties. **Interact**, trade name for the joining material, is a "reaction eutectic," which under the influence of heat eliminates the surface oxide layer and causes similar and dissimilar metals to flow together at temperatures lower than the melting point of either metal being used. Automotive, appliance, construction and electrical manufacturing are some of the industries in which the process can be used.

Adhesives Dept. of Raybestos-Manhattan, Inc., Bridgeport 2, Conn., is marketing three new adhesives for bonding treated Teflon to other materials or to itself. The adhesives, designated as Ray-Bond R-86004, R-86024 and R-81001 permit effective bonding of treated Teflon to wood, steel, glass, aluminum, copper, ceramics, plastics or any other material that will bond with an adhesive. Detailed information will be sent free upon request.

Atomic Energy

Liquid Metal fuel reactor with a concept different from those presently in progress has fuel circulating inside reactor rather than being part of stationary fuel elements. Uranium-bismuth liquid fuel will circulate through graphite lattice and external heat exchangers, according to A. D. Little, Inc., Cambridge, Mass. now conducting a feasibility study on the system.

Boilers

Boiler designed to operate at 1900 psi at superheater outlet and with steam and reheat temperatures at 1000 F is being built for Duquesne Light Company at Elrama, Pa. by Babcock & Wilcox Co. The boiler will have a maximum continuous output of 1,300,000 pounds of steam an hour and will burn 75 tons of coal hourly.

Cathodic Protection

Cathodic Protection systems for protection of hulls of ships will be tested on a floating marine laboratory vessel recently built by Charles Englehard, Inc. The 23-foot vessel has specially built electrical connections to the hull for testing cathodic protection installations.

Cleaners

Harco Chemical Co., Cranford, N. J., has originated a safety cleaning solvent for wipe or dip cleaning of greasy and oily machine parts and electrical equipment. The new cleaner replaces carbon tetrachloride and other chlorinated sol-

vents and has no flash point in normal use. It compares in toxicity to Stoddard solvent and has high solvent power with very rapid evaporation.

Mono-Seal Products, 44 Garden St., Everett 49, Mass. has developed a tough, plastic-type protective coating formulated from a special blend of silicones and epoxies with good corrosion resistance, impact resistance, long life and weather and moisture resistance. The coating will protect against a wide range of acids, alkalis, oils, solvents, plaster-cizers, moisture, weathering, abrasion, impact and temperature extremes. It is designed for use on equipment, structures, tanks, floors, trucks, boats, ships and machinery.

Coatings

Lining for oil field tubing by a continuous electrically controlled machine process is described in a brochure issued by Tubular Lining Corp., P. O. Box 20015, Houston 25, Texas.

Carbide Coating can be deposited on graphite parts by a new process developed by Horizons Inc., 2905 East 79th St., Cleveland 4, Ohio. Coatings on machined parts cover undercuts, holes, drilled areas, milled sections at controlled thicknesses from 40 to 250 microns.

Better Finishes and Coatings, Inc., 268 Doremus Ave., Newark 5, N. J. reports that one application of the urethane provides a coating highly resistant to corrosion. Resistance to heat, sunlight, water and weather are unusually good, and flexibility and abrasion resistance are excellent, the firm says. Urethanes were developed in Germany during World War II and are now used there widely in steel mills, chemical plants and heavy industry. The product is made in the United States and is available in white and 12 colors.

Form-Saver, a quick-drying protective coating with durable, smooth finish for plywood form panels is described in a brochure available from Building Products Div., Dept. FS, L. Sonneborn Sons, Inc., 404 Fourth Ave., N. Y., N. Y. The circular gives information on advantages and features of Form-Saver which extends the life of plywood forms and makes possible many re-uses of the forms before recoating is necessary.

Sun Chemical Corp., Long Island City, N. Y., has signed a contract to buy Ansbacher-Siegle Corp., pigment manufacturers. The new Sun subsidiary will continue to produce pigments for paints and plastics and other coloring uses.

Dow Corning Corp., Midland, Mich., is producing commercial quantities of a new silicone intermediate that can be polymerized with a variety of organic resins. Identified as Z-6018, it can be chemically combined with most paint resins to produce finished films with

improved color and gloss retention, weatherability, moisture resistance, heat stability and wet and dry electrical properties. It is manufactured in dry, flake form.

Porcelain Enamel for curtain walls and veneer construction is described in publications available from the Porcelain Enamel Institute, Inc., Associations Bldg., 1145 Nineteenth St., N. W., Washington 6, D. C. A 12-page brochure published by the institute pictures some examples of building trim, wall construction and the use of enamels for outdoor cooking and picnic ware.

Coroline is the trade name for a "corrosion-proof" thermo-setting coating material made by Celco Co., Inc., 4874 Ridge Rd., Cleveland 9, Ohio. According to the company, the coating was developed originally for the lining of plating tanks, pickling tanks, cyanide tanks and other like equipment to provide maximum resistance to chemical action. However, it has been found to be excellent protection against corrosion for exhaust fans moving corrosive atmospheres. For complete specifications, write William Smith, president, on company letterhead.

Synthetazine 300, the new, improved lining which "offers greater protection to a larger number of hard-to-package products in steel shipping containers" is manufactured by Synthetazine Protective Coatings, Inc., 600 Fifth Ave., New York 20, N. Y. Although the product is sold through licensees, a leaflet describing the product in detail may be obtained by writing the manufacturer.

Drills

Linde Co., Div. Union Carbide Corp. has developed a jet-piercing rock drill. Jets of flame at 4000 F, with the blast traveling five times faster than sound disintegrates or spalls the rock in its path. Distintegrated rock particles are thrown up out of the hole by the burning gases and steam. The process is highly efficient on the hardest rocks. Taconite, rich in iron ore, wears out the toughest drills in minutes. Jet-piercing blasts holes 40-ft. deep and 7-in. wide in Taconite at speeds from 12 to 40 ft. an hour.

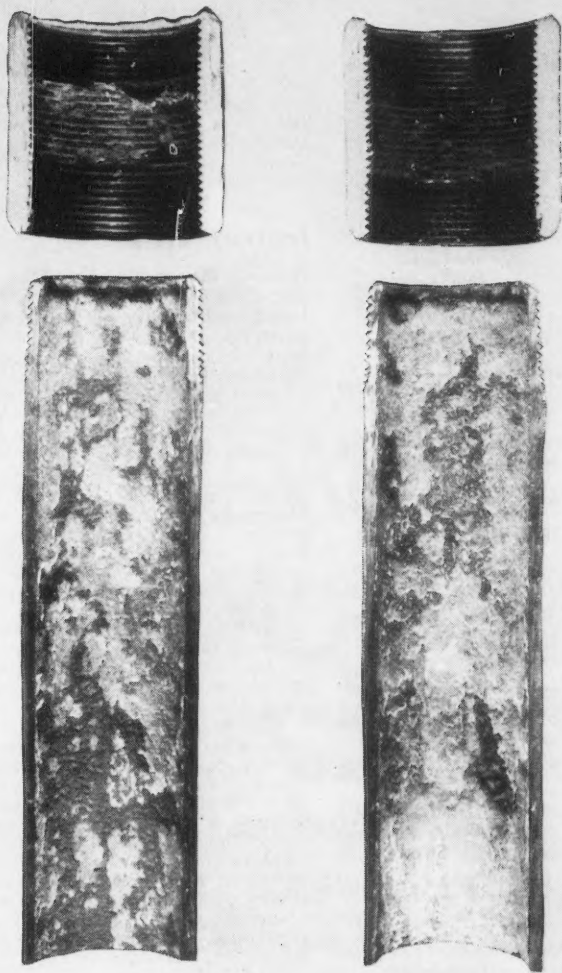
Engineering

Ebasco Services Inc. has moved its Central Regional office to the Field Building, 140 S. Clark St., Chicago 3, Ill. R. H. Bradford is office manager. The office facilitates relations with Ebasco and its clients in the Midwest. The firm provides engineering, construction and business consulting services.

Water Service Laboratories, Inc., 423 W. 126th St., N. Y. 27, N. Y., has expanded both its physical plant and its services. A more extensive program of research on water corrosion is planned,

(Continued on Page 120)

another Wrought Iron case against corrosion



30

YEARS OF SERVICE

Longitudinal photomicrograph U-44-2 (100x) shows a typical area—parallel to rolling—of the microstructure observed in the subject 1½" wrought iron pipe.



Metallurgical Report '6900—Hot Water Line*

This report deals with the metallurgical examination of a length of 1½" wrought iron pipe with coupling, submitted to our laboratory for investigation and comment.

The sample submitted had been in service for 30 years as a hot water line, yet was found to be in excellent condition. The inner surface of the pipe showed light, tightly adherent products of corrosion. Underlying galvanizing on the inside of the pipe was virtually intact.

Drillings taken from the pipe analyzed as follows: Carbon—.018%; Manganese—.050%; Phosphorus—.142%; Sulphur—.018%; Silicon—.174%; Iron Silicate—3.45%.

Wrought iron pipe's 30 years of unflinching service

in this installation may be traced to its unique defensive network of glasslike iron silicate fibers. Service records such as this one present a very strong case for wrought iron pipe's outstanding corrosion resistance. A. M. Byers Company, Clark Building, Pittsburgh 22, Pennsylvania.

*Name of actual installation given on request.

Write for free cloth-bound book, *Wrought Iron: Its Manufacture, Characteristics and Applications*.

BYERS

WROUGHT IRON

NEW PRODUCTS

(Continued From Page 118)

and an additional 18,000 square feet of office space has been leased. The firm has specialized in the treatment of water against corrosion in residential and commercial buildings for 30 years.

Filters

Hi-eF Purifiers, designed to operate at pressures up to 1500 psi in air, steam and process vapor and gas lines are made of alloy steels with special gaskets and pipeline connections by High Pres-

sure Vessel Section, Purifier Division, V. D. Anderson Co., 1935 West 96th St., Cleveland 2, Ohio.

Tyrl, high strength solvent resistant plastic filters are made in graded density by Cuno Engineering Corp., Meriden, Conn.

The National Filter Media Corp., 1717 Dixwell Ave., New Haven, Conn., has published new information on all types of filter cloth. Fabrics covered include Nylon, Dacron, Vincel, Orlon, Dynel, Teflon, Saran, cotton, glass, polyethylene and special filter papers. Bulletin No. 10 also gives data on chemical resistance, corrosion resistance, abrasion resistance and available yarn forms for each type of cloth.

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Heat Exchangers

Falls Industries, Inc., Aurora Rd., Solon, Ohio, has improved the design for their Impervite tube and shell type heat exchanger. The new design keeps the impervious graphite in the floating end under constant compression. It is claimed that greater strength to the floating end of the exchanger is provided as is also a more positive packing between the machined metal surfaces of the tube sheet skirt and the shell flange. Graphite is used to provide protection against highly corrosive substances. More information may be obtained from John Reys, the company's chief engineer.

Instruments

National Carbon Co., Div., Union Carbide Corp. has developed an arc image furnace for research use producing temperatures above 7000 F. The furnace uses two mirrors to concentrate the beam from a carbon arc light on the material to be heated. More information may be secured by writing William Esty Co., Inc., 100 E. 42nd St., N. Y., N. Y.

Branson Ultrasonic Corp., 40 Brown House Rd., Stamford, Conn., has developed a new ultrasonic cleaning generator for pilot-plant or production application. The apparatus will usually remove insoluble soils and contaminants more quickly than other methods. Oil in sintered parts, blind holes and complicated crevices is washed out easily. As long as a surface is in contact with the cleaning liquid, cleaning will take place, the firm states.

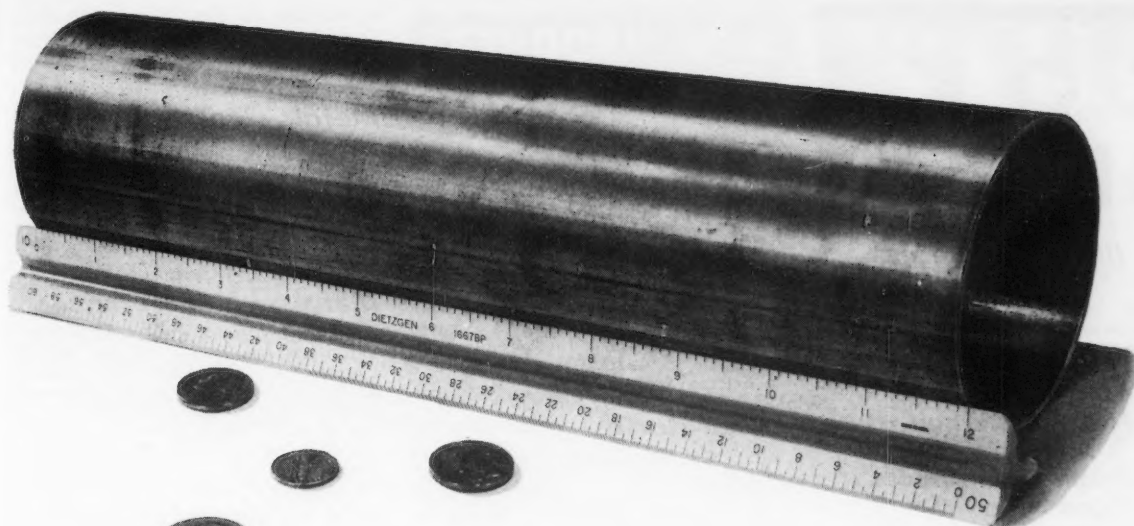
Alternating Gradient synchrotron to be built at Atomic Energy Commission's Brookhaven National Laboratory will have 246 magnet cores producing 25 to 30 billions electron volts. Eddystone Div., Baldwin-Lima-Hamilton Corp. will build the magnets. The machine is expected to have four to five times the energy of other similar machines in the United States and three times that of the 10-billion-volt machine built by Russia in 1957.

AccuRay portable pipewall thickness gauge developed by Industrial Nuclear Corp., 1205 Chesapeake Ave., Columbus 12, Ohio is designed to measure pipe wall thickness from one side with an accuracy of plus or minus 0.010 inch. The measuring principle of the transistorized instrument is not described.

Betatron rated at 24 million volts is being used by Electric Steel Foundry Co., Portland, Oregon to inspect 20 inches of steel for defects.

Ultrasonic testing of lead, laminated plastics, castings, severely corroded sections and other poor transmitters of ultrasonic energy is possible with a new transducer with increased sensitivity developed by Branson Instruments, Inc., Stamford, Conn. Flaws can be detected very close to tested surface and the immersion mounted device is designed for continuous operation at temperatures up to 250 F. Contact types can be operated up to 450 F.

(Continued on Page 122)



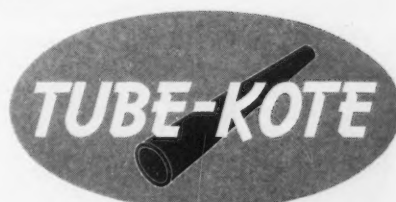
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Tube-Kote's leadership in baked-on plastic coating—*built on 18 years of research and experience*—makes possible this newest reduction in cost. New techniques, new materials, plus the industry's greatest experience combine to make this new price cut possible.

So, along with bringing you the industry's lowest prices, Tube-Kote also brings you the industry's best tested application techniques and the industry's newest types of coatings. There are different Tube-Kote formulas to overcome each of your problems in corrosion. Each of them is the standard for others to follow.

Now, with steel prices rising and with the cost of complete Tube-Kote baked-on plastic protection cut, savings become even more significant. A Tube-Kote engineer will explain the advantages of the different Tube-Kote coatings to you. Call him for the full story on how Tube-Kote's leadership will benefit you.

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Ideally suited for use with anodes. Has a high carbon content and comes in sizes of $\frac{1}{8}$ -inch x 0 to $\frac{3}{8}$ x $\frac{7}{8}$ -inch. In bulk or sacks. Prices on other sizes on request.

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MT. OLIVE, ALABAMA**

NEW PRODUCTS

(Continued From Page 120)

Insulation

Dow Corning C-271 silicone adhesive mixed with asbestos "shorts" provides a lightweight thermal insulation covering which also is highly resistant to vibration and abrasion, according to the Midland, Mich. firm. Presently the coating is being used by Cessna Aircraft, which developed the compound. A cured film, only 0.13 inch thick reduces internal duct temperatures of 450 F down to external temperatures of 150 F.

Laboratories

Linde Co., Div., Union Carbide Corp. will construct new facilities for its Tonawanda Research Laboratories for basic research in the fields of cryogenics, organic and inorganic chemistry and flame technology. A high-pressure laboratory, metallurgical laboratory and a new hydrocarbon storage building are to be constructed. The high-pressure laboratory will incorporate equipment capable of producing gas and liquid pressures up to 200,000 psi.

Lubricants

Railroad 60, a graphite lubricant developed by Joseph Dixon Crucible Co., 167 Wayne St., Jersey City, N. J. has performance superior to oil and greases coatings on railroad switches and plant sidings. The lubricant, applied like paint,

is resistant to contamination by brine drippings, oil and grease drippings, weed killers and other corrosives from -40 to plus 115 F.

Metals—Ferrous

Stainless Steel products for architects and builders are described and illustrated in a 44-page manual available from Committee of Stainless Steel Producers, American Iron and Steel Institute, 150 East 42nd St., New York 17, N. Y.

Metals—Non-Ferrous

Aluminum Alloy containing 2.75-3.25% boron has been developed by Kawecki Chemical Co., 220 East 42nd St., New York 17, N. Y. as a complimentary master alloy to its 1.50-2.25% boron-aluminum.

Columbian melting stock of the highest purity ever made available commercially is being produced by Electro Metallurgical Co. Division of Union Carbide Corp. in the form of small cylindrical shapes.

Titanium and titanium alloys are being rolled into foil with minimum thicknesses of 0.001-inch to 0.003-inch depending on the grade and alloy. All can be annealed. Profile rolled shapes resembling an "L" also have been produced in commercially pure titanium and similar shapes in alloys are contemplated.

Non-Metallics

Nylon fittings for use with plastic pipe have been developed by Franklin Plastics, Inc. Franklin, Pa.

AF 20, highly expanded polystyrene supplied in 4-inch thick blocks by Gulton Industries, Inc., 212 Durham Ave., Metuchen, N. J. give permanent radar darkness. A structure covered with the material becomes invisible to a radar beam.

Vitrified Clay channel-drain channel pipe designed by Dow Chemical Company and manufactured by Logan Clay Products Co., Logan, Ohio is made for permanent installation in floors for drainage of corrosive wastes. An illustrated brochure is available on request.

American Industrial Chemical Company, Division of Amerace Corp., Cooper Park, Butler, N. J. offers its 4-page Bulletin No. MAC on new silica gels, hydro gels and other synthetic silicas.

Activated Carbon molded into cubes approximately $\frac{3}{8}$ inch on a side are available from National Carbon Company, 1300 Lakeside Ave., Cleveland 14, Ohio to be enclosed in cases of electronic devices whose components may emit corrosive gases damaging to the equipment. The carbon absorbs vapors given off by plastic insulation, for example.

Plastics

Celluflex 21 and 23, developed by Celanese Corp. of America, 180 Madison Ave., New York 16, N. Y. impart

(Continued on Page 124)

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you need and the
service you deserve*

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**INDUSTRIAL
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PREVENTION**

protection with **KONTOL**

INCREASES RUN TIME 33 $\frac{1}{3}$ %*

In a midcontinent refinery atmospheric tower the effects of Kontol corrosion control were carefully compared to previous 6 month refinery runs. During the former runs, corrosion control was attempted by injecting ammonia into the atmospheric tower overhead to maintain a pH of about 7 in the overhead accumulator water. The run with Kontol was identical except that running time was increased from 6 to 8 months.

Operations during both runs were observed by refinery personnel and results reported as follows:

INSPECTION DEPARTMENT

Metal loss in test plugs (vapor line, crude-to-vapor heat exchanger):

- Without Kontol, Plug "A", 0.10 inches
- Without Kontol, Plug "B", 0.05 inches
- With Kontol, Plug "A", 0.01 inches
- With Kontol, Plug "B", 0.02 inches

Exchanger Fouling:

Visual inspection showed a decrease of 80-90% in fouling with Kontol in use.

Tower Trays:

- Without Kontol, 8 manhours cleaning time
- With Kontol, no cleaning required

OPERATING DEPARTMENT

Heat Transfer Rates at 1500 bbls/hr charge rate:

- Without Kontol, exchanger crude outlet temperature, 187° F
- With Kontol, exchanger crude outlet temperature, 192° F

Heat Transfer Rates at 1000 bbls/hr charge rate:

- Without Kontol, exchanger crude outlet temperature, 210° F
- With Kontol, exchanger crude outlet temperature, 231° F

LABORATORY DEPARTMENT

Iron count, atmospheric tower overhead water:

- Without Kontol, 6.1 ppm
- With Kontol, 2.2 ppm*

*During first week of Kontol applications iron count averaged 100 ppm, indicating the sloughing off of fouling materials effected by Kontol's detergent action.

As a result of the data on these two refinery runs, the refinery personnel concerned recommended the use of Kontol be extended to all points where fouling due to iron sulfide might occur in exchangers and towers.

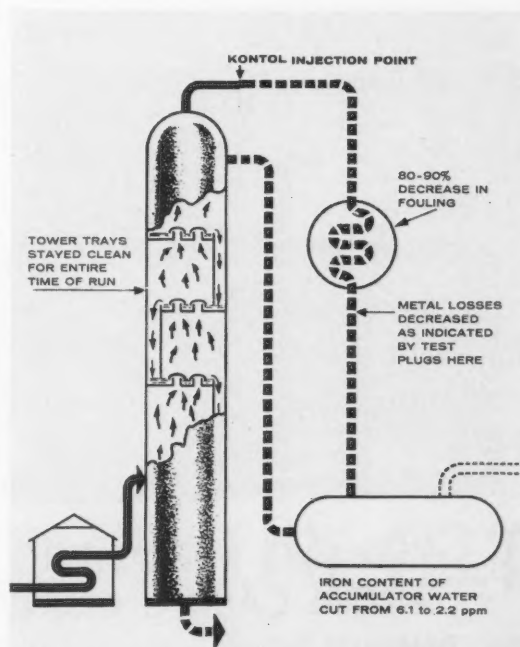
Leading refiners everywhere rely on Kontol for preventing corrosion difficulties. Your Tretolite Refinery Service Engineer is always available for consultation. Call him today or write for complete information.

It also "Reduced heat exchanger fouling 80-90%"

"Improved heat transfer rates"

"Made tray cleaning unnecessary"

*Resulted in the longest run on record at this refinery



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METAL DEACTIVATION

NEW PRODUCTS

(Continued from Page 122)

low temperature properties and improved stability to polyvinyl chloride and other materials.

Furane Plastics, Inc., is marketing a new curing agent, Hardener 929 for epoxies which, the firm states, will permit the development of high temperature property epoxies. Applications include not only high temperature tools, such as bonding jigs and fixtures for aircraft and welding equipment for metal industries but also high temperature electrical service and important maintenance functions. Address of the company is 4516 Brazil St., Los Angeles 39, Calif.

A. M. Byers Co., Clark Bldg., Pittsburgh, Pa. has published a 30-page catalog giving detailed information on polyvinyl pipe which the firm will market throughout the nation. Corrosion resistance of polyvinyl pipe is compared in the brochure with other materials in an 8-page chart listing comparative resistance to 383 chemicals. Pressure temperature curves, applications, recommended working pressures, installation, trained personnel and other information is detailed in the publication.

Moplen, a new thermoplastic now in commercial production in the Ferrara, Italy plant of Montecatini, Societa Generale, Milan, Italy is made by a new method of synthesizing olefins which produces an unusual regularity of structure and a controlled crystallinity in the

plastic. The material can be used in pipe and fittings, in textile machinery parts, electrical and mechanical components, pump parts, automotive parts and other objects. It is said control of crystallinity provides the material with high strength, high heat resistance, resistance to solvents and unusual electrical properties.

Aurand Mfg. and Equipment Co., 1210 Ellis St., Cincinnati 23, Ohio has developed electrical and air driven power brushes designed for surface preparation of metals prior to painting. Loose-pin-ion cutters in the toothed wheels hit the surface to loosen rust. Depth of cut is controlled by a shoe.

Welding

All-State Welding Alloys Co., Inc., White Plains, N. Y. is producer of No. 275, a chromium-nickel AC-DC electrode for uses requiring high strength and great resistance to corrosion, impact and heat. It is recommended for use with very high alloy steels, tool and spring steels, pressure vessels, air hardenable steels, dies, nickel clad and mild and medium carbon steels.

Oxweld W-47, a new welding blowpipe capable of welding any metal thickness from 28-gage sheet to 3-inch plate is described in an 8-page booklet published by the Linde Co., Div., Union Carbide Corp. The blowpipe handles gas flows as low as 2 cu. ft. per hr. for precision welding, or as much as 1500 cu. ft. per hr. for heavy heating operations. The booklet may be obtained by writing to Linde Co., Div., Union Carbide Corp., 30 E. 42nd St., New York, 17, N. Y.



200 GAS WELLS PROTECTED FROM CASING CORROSION

Problem. To protect the casing in more than 200 gas wells from external corrosion. These wells are in the Kansas section of the Hugoton gas field, and are operated by four companies. Six of the wells are in the sand hills area where soil resistivities are of the order of 20,000 ohm-cms.

Solution. CSI engineers made current requirement tests, and then applied cathodic protection using Galvomags—Dow's high-potential magnesium anodes.

Installations were designed to provide a guaranteed current output, with a minimum protection of 10 years. Current requirements ranged from 0.43 to 2.05 amperes. Costs averaged about \$325 per well.

For expert consultation, engineering services or cathodic protection materials, call or write today. Estimates or quotations without obligation.

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MEN in the NEWS

A. S. Chalfant has been appointed director of steel sales of A. M. Byers Co., Pittsburgh.

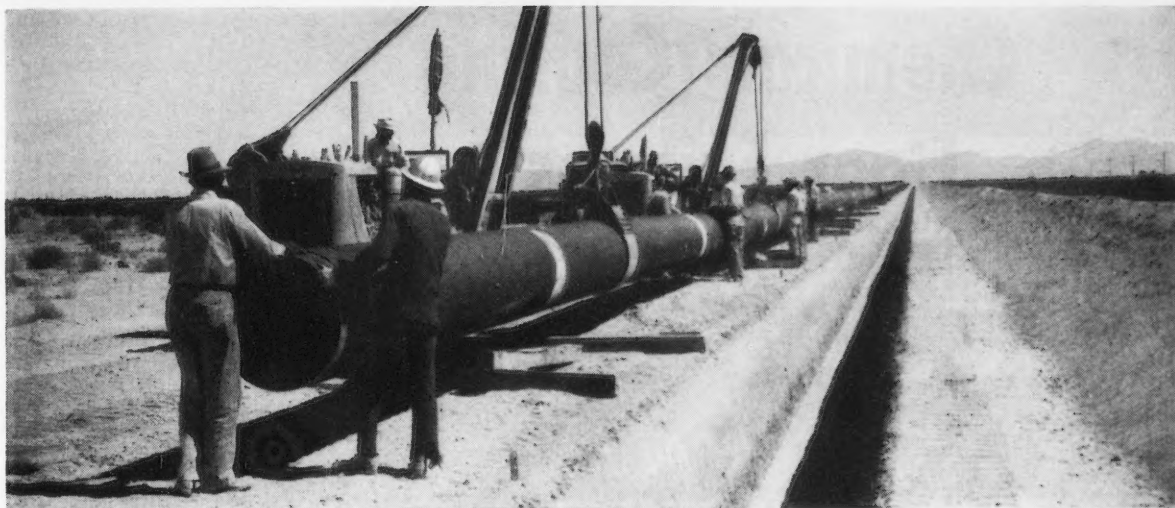
James A. Kessekert has been appointed to the newly-created position of manager-production planning and scheduling for the paint and brush division of Pittsburgh Plate Glass Co.

Francis Leslie Scott has been appointed to the post of project leader in Pennsalt Chemicals Corporation's technical division. He will conduct basic research in organic nitrogen chemistry to develop new and useful products from ammonia.

John H. Caldwell has been promoted to assistant sales manager, protective coatings division, Pittsburgh Coke & Chemical Co. Mr. Caldwell will supervise regional sales managers in New York, Chicago, Houston and Los Angeles. He is a member of National Association of Corrosion Engineers. The company sells tar base coatings and gilsonite-asphalt mastics made by Insul-Mastics, Inc.

Roy E. Slipiec was recently made Midwest sales representative of Geigy Industrial Chemicals, Division of the Geigy Chemical Corp. His sales headquarters are located at 629 W. Washington Blvd., Chicago, Ill.

(Continued on Page 126)



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PIPE WRAP "B"
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100 sq. ft.—12.5 pounds
Wt. of Fiber per 100 sq. ft.—1 pound

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from your Carey Sales Engineer or
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ASBESTOS PIPELINE FELT

Heavy soil conditions can really play havoc with pipeline coating. That's why coating alone can't possibly give your lines positive protection against soil stress. The answer is a protective wrapper between soil and coating to prevent transmission of stress. Equally important is selecting the best pipe wrap to do the job.

What should you look for in wrapping materials? Well, weight contributes greatly to the strength of the wrap, but the controlling factor is the percentage of fiber content. Carey As-

bestos Pipeline Felt, as the chart shows, has 10 times more fiber. This toughens the wrapping material against continual stress, caused by the shifting of soil. Unless there's an adequate amount of fiber the wrap will tear, breaking the coating and exposing the pipe to corrosive action.

Before you buy pipe wrap, compare—not just weight but fiber content as well. Carey No. 15 Asbestos Pipeline Felt assures you better protection, better performance, from the coatings you use.

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TRUSCON

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Devoe & Reynolds Co., Inc.



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MEN in the NEWS

(Continued From Page 124)

R. K. Turner has been appointed president of Bakelite Co., Division of Union Carbide Corp. He succeeds **George C. Miller**, who has been appointed president of Union Carbide Realty Co. The corporation's realty operations are extensive.

Paul Dyer Merica, retired president of The International Nickel Co. of Canada, Ltd., died Oct. 20 in Tarryton, N. Y. from a heart attack. He was 68. He first joined International Nickel in 1919 and through the years, had held various executive positions in the organization. He was a director of five subsidiary firms of International Nickel.

Frank R. S. Kaplan died Oct. 4, 1957. He was chairman of the board of Copperweld Steel Co., and was one of the founders of the firm in 1915.

Harry A. Robertson, Jr. has been assigned a new sales territory in the central section of Ohio for the Garlock Packing Co., Palmyra, N. Y.

Wendell G. Markham has joined Tretolite Company of California, division of Petrolite Corp. as a research chemist. For the past 11 years Mr. Markham has been associated with B. J. Service, Inc., in the capacity of chief chemist working in the fields of oil well cementing, production, stimulation and corrosion.

Chester A. Lawton is manager of American Potash and Chemical Corp., district office at 12 North Third St., Columbus, Ohio.

Thomas A. Bissell has been appointed executive secretary of the Society of Plastics Engineers, Inc.

W. J. Kretschmer, Columbia Gas System Service Corp., Columbus, Ohio received the American Gas Association's Operating Section Award at St. Louis October 7. The award gives public recognition to men whose activities in the section have been outstanding. He has been chairman of the section's Underground Corrosion Mitigation Practices Subcommittee.

Sidney E. Trouard, New Orleans Public Service, Inc., New Orleans was recipient of American Gas Association's Distribution Achievement Award given annually to the person whose contributions to the science and art of gas distribution have been outstanding during the past five years. In particular his achievements in connection with application of cathodic protection were signalled.

James W. Vicary, president of Ervite Corp., Erie, Pa. has been reelected president of the Porcelain Enamel Institute.

Frederick Nims Rhines, professor of Light Metals at Carnegie Institute of Technology has been given the American Society for Metals Henry Marion Howe Medal for the best paper published in the society's transactions during 1956.



TECHNICAL TOPICS

1. BINKS SPRAY NOZZLE—SERIES 50-100
2. ORIFICE PLATE
3. HIGH PRESSURE GAS TAP
4. FILTERS
5. CHEMICAL FEED TANK
6. CHEMICAL STORAGE TANK
7. NEEDLE VALVE

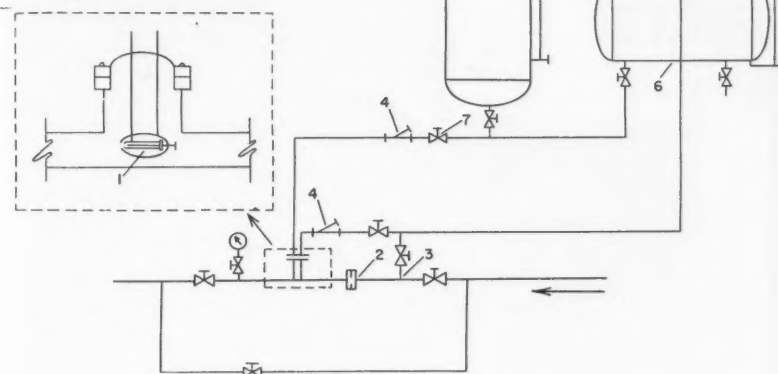


Figure 1—Equipment for injecting liquid chemicals into high pressure gas systems.

Spray Injection of Liquids Into High Pressure Gas Lines*

Introduction

A TECHNIQUE has been developed for injecting liquids in the form of a vapor or mist into high pressure gas systems. Development of this technique resulted from the need to inject a liquid organic corrosion inhibitor into a 26-mile, high-pressure gas transmission line (4-inch line—600 psig). Because of the terrain through which the line passed, it was impractical to inject inhibitor at any point other than at the origin of the line. Previous experience^{1,2} indicated that putting the inhibitor into the line in liquid slugs would not be satisfactory. It was felt that if the inhibitor was dispersed in the line as a fine mist, it would be carried in suspension through the full distance from one injection point³.

A satisfactory technique was developed for spraying inhibitor into this line. Similar apparatus was used later for injecting inhibitor into high pressure gas systems used for lifting fluid from oil wells. In this latter case, inhibitor traveled with the gas to the wells, into the tubing-casing annuli of the wells, through the gas lift valves and into the well tubing.

The method should be equally successful for injecting any liquid into high pressure gas lines regardless of the ultimate use of the gas.

Method of Injection

The technique developed for spraying chemicals into high pressure gas lines is shown schematically in Figure 1.⁽¹⁾ Figure 2 is a photograph by-pass arrangement at an actual installation. Referring to Figure 1, the method is explained as follows:

A commercially available atomizing nozzle⁽²⁾ (1) is positioned in the center of the gas flow line so that the nozzle will spray in the same direction as the gas flow. An orifice plate (2) is placed in the line immediately upstream of the nozzle. Using this particular spray nozzle, the orifice size is chosen in order that a minimum of 10 and a maximum of 20 psig pressure-drop across the orifice results. The gas system is tapped on the high pressure side of the orifice (3). The high pressure gas is piped through a filter (4) into the air side

Abstract

A method of adding inhibitors as spray to high pressure gas lines is described. The method uses pressure differential created by an orifice plate upstream of a spray nozzle in a device which has no moving parts, gives satisfactory dispersal of inhibitor through a 26-mile line and through a gas lift system, and requires very little maintenance other than refilling tanks with inhibitor. 5.8.2

of the atomizer (1) and into the top of the chemical feed tank (5) and chemical storage tank (6). The chemical is fed to the atomizer (1) from the chemical feed tank (4) through a needle valve (7) and filter (4). Other valves and gauges are provided as shown.

The arrangement shown offers maximum flexibility of operation since chemical can be fed to the nozzle from either tank separately or from both tanks simultaneously. Either tank can be filled separately and chemical can be transferred from one tank to the other without interrupting chemical feed to the nozzle.

The nozzle can be adjusted to spray as little as 8 gallons and as much as 30 gallons of liquid in 24 hours. If it is desirable to treat with less than 8 gallons of chemical per day, the volume should be increased by dilution with a solvent.

Cost—Maintenance—Operation

The entire assembly described was constructed for approximately \$2000. Excluding the by-pass valves, the cost was approximately \$1100.

The combined operating time of the units, built to date is approximately four years. All units have required less than ten man-days maintenance time during this period.

The unit operates without moving parts and the feed is approximately automatic and constant as long as a pressure drop exists across the orifice. Periodic

(Continued on Page 128)

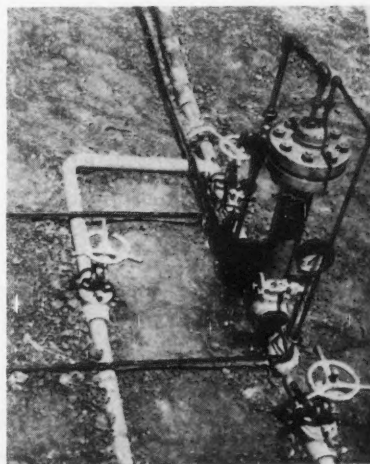
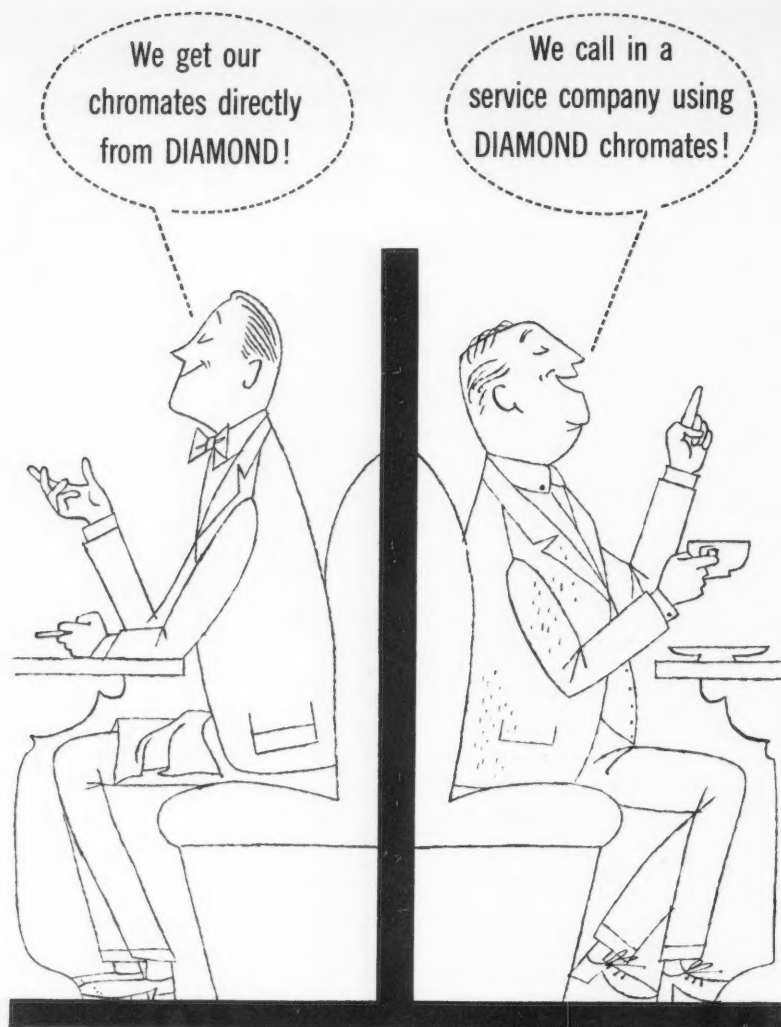


Figure 2—By-pass arrangement.

* By F. E. Blount and J. W. Anthony, Magnolia Petroleum Company, Field Research Laboratory, Dallas, Texas.

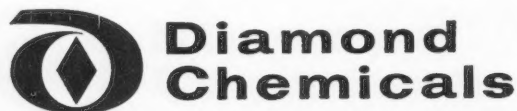
(1) Details of the system are being covered by application for United States Letters Patent.
(2) Binks Manufacturing Company, Chicago 12, Illinois—Series 50-100 nozzle or equivalent.



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Spray Injection—

(Continued From Page 127)

replenishment of the chemical in the storage and feed tanks is, of course, necessary.

A qualitative test for the corrosion inhibitor indicated that it was carried the full length of the 26-mile line and completely through the gas lift system.

Summary

A technique has been developed whereby liquids can be injected in the form of a vapor or mist into high-pressure gas transmission lines, into high pressure gas systems used for lifting fluid from oil wells, or into high pressure gas systems regardless of the ultimate use of the gas. Injection of liquid in this manner allows the liquid to travel with the gas for long distances.

The method has been used for injecting liquid organic corrosion inhibitors into 1) a sour gas transmission line and 2) high pressure gas systems used for lifting oil well fluids. Other chemicals designed to prevent emulsions, hydrate formation, etc., could be injected in this same manner.

Acknowledgment

The authors express their appreciation to the Magnolia Petroleum Company for permission to publish this paper. Credit is also due to the following persons for their assistance in the development of this technique: Messrs. J. B. Miller, L. G. Sharp, W. A. Shulaw, R. J. Swain, of Magnolia Petroleum Company; and T. C. Smith of Mobil Producing Company.

References

1. W. Swerdloff and Maryann Duggan. Experience With a Corrosion Control Program for a Unit Dehydrating Gas with Diethylene Glycol. Paper presented at NGAA Meeting, Dallas, Texas, April 1955.
2. Felipe Paredes and W. W. Mize. Unusual Pipeline Failures Traced to Hydrogen Blisters. *Oil and Gas Journal*, Page 99, December 20, 1954.
3. Kowenstrot and Wohlrabe, U. S. Patent No. 2728619.



TECHNICAL REPORTS

on

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Structure, Characteristics and Uses of

URETHANE COATINGS*

Abstract

Molecular configuration of the isocyanate polymers is given, together with a brief explanation of the linkages which give the coatings and materials derived from them their properties. Examples are related and illustrated of successful service use of urethanes in Germany. Results of laboratory tests versus competitive high grade coatings submerged in water and subjected to several chemicals are described and illustrated.

A new isocyanate adduct containing less than one percent of the irritating free tolylene diisocyanate monomer is being produced. This material is improved to the extent that no precautions not presently used in handling coatings containing solvents are required.

54.5

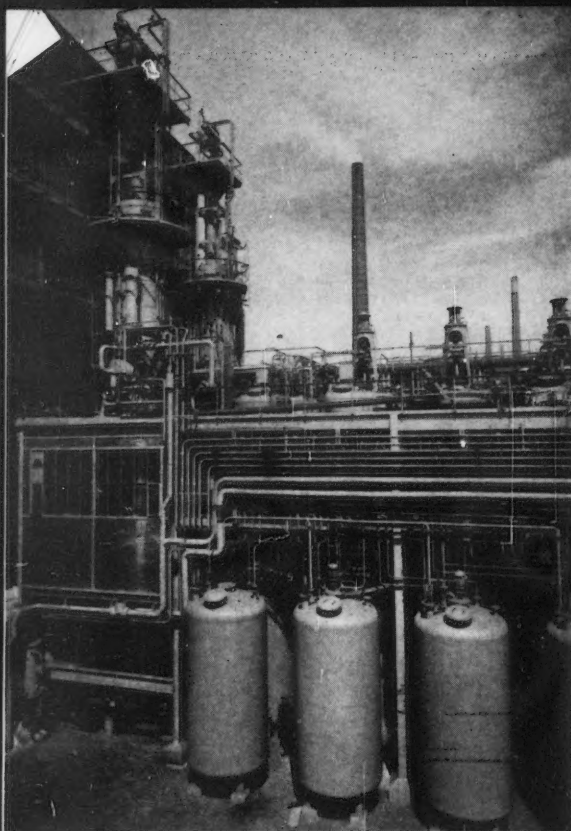


Figure 6—Series of tanks at Bayer plant in Germany exposed to a chemical atmosphere shown after a year's service.

URETHANES, perhaps the newest major entry in the field of plastics in this country offer through a group of new chemical materials types of coating which can be formulated with great versatility, which have unusual combinations of good solvent, fresh and salt water and good chemical resistance and excellent general physical properties.

Urethane surface coatings are one of many in this new series of commercial products which in addition to being called "urethanes," sometimes are referred to as poly-urethanes or isocyanate polymers.

Urethane rubber is a product which exhibits phenomenal properties as a low or high durometer elastomer with excellent abrasion and impact resistance, vibration absorption, solvent resistance and aging characteristics. Urethanes also have made possible soft, flexible adhesives resistant to dry cleaning solvents and normal soap and water washing. All of these products are directly related to urethane coatings because of similar isocyanate chemical reactions.

Urethane coatings are chemically cured by the reaction of isocyanate⁽¹⁾ adducts with one, or a combination of specially selected polyester resins.

Mondur TD, which is tolylene diisocyanate is generally referred to as TDI. Structurally, it appears as in Figure 1.

Tolylene diisocyanate is a water thin straw colored liquid. It is the most widely used of the diisocyanates because of its relative ease in manufacture and lower cost. Reacted with different polyols it makes a series of trifunctional isocyanate adducts called Mondur C, Mondur CB and Mondur S. Structure of Mondur CB would be similar to that shown in Figure 2.

These isocyanates or adducts are combined in coating formulations with hydroxyl terminated polyester resins. The polyesters may vary from a long linear structure to a highly branched structure—both terminated with hydroxyl groups, as illustrated in Figure 3.

The chemical reaction that takes place with the mixing of an isocyanate adduct such as Mondur CB and a polyester resin is between the isocyanate radical (NCO) and the terminal hydroxyl groups of the polyester as shown in Figure 4 which shows formation of what is called a urethane linkage. It is from this reaction that the term "urethane" is obtained.

The function of the isocyanate is to build large molecules from many small ones. In urethane coating formulation, isocyanate groups react with the hydroxyl terminals of different polyester molecules, thus linking them and building a cross-linked molecular structure which gives the coatings their characteristic mechanical, chemical, solvent and moisture resistant properties.

Four factors which generally deter-

Continued on Page 132)

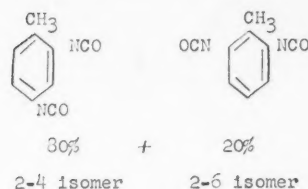


Figure 1—Structure of 80/20 tolylene diisocyanate.

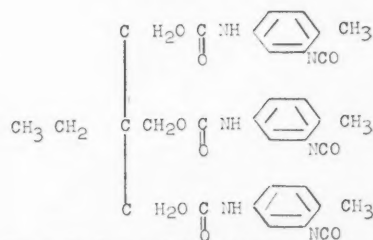


Figure 2—Representative structure of Mondur CB.

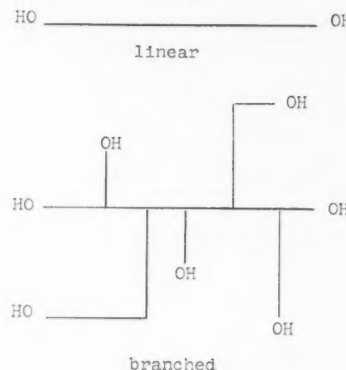


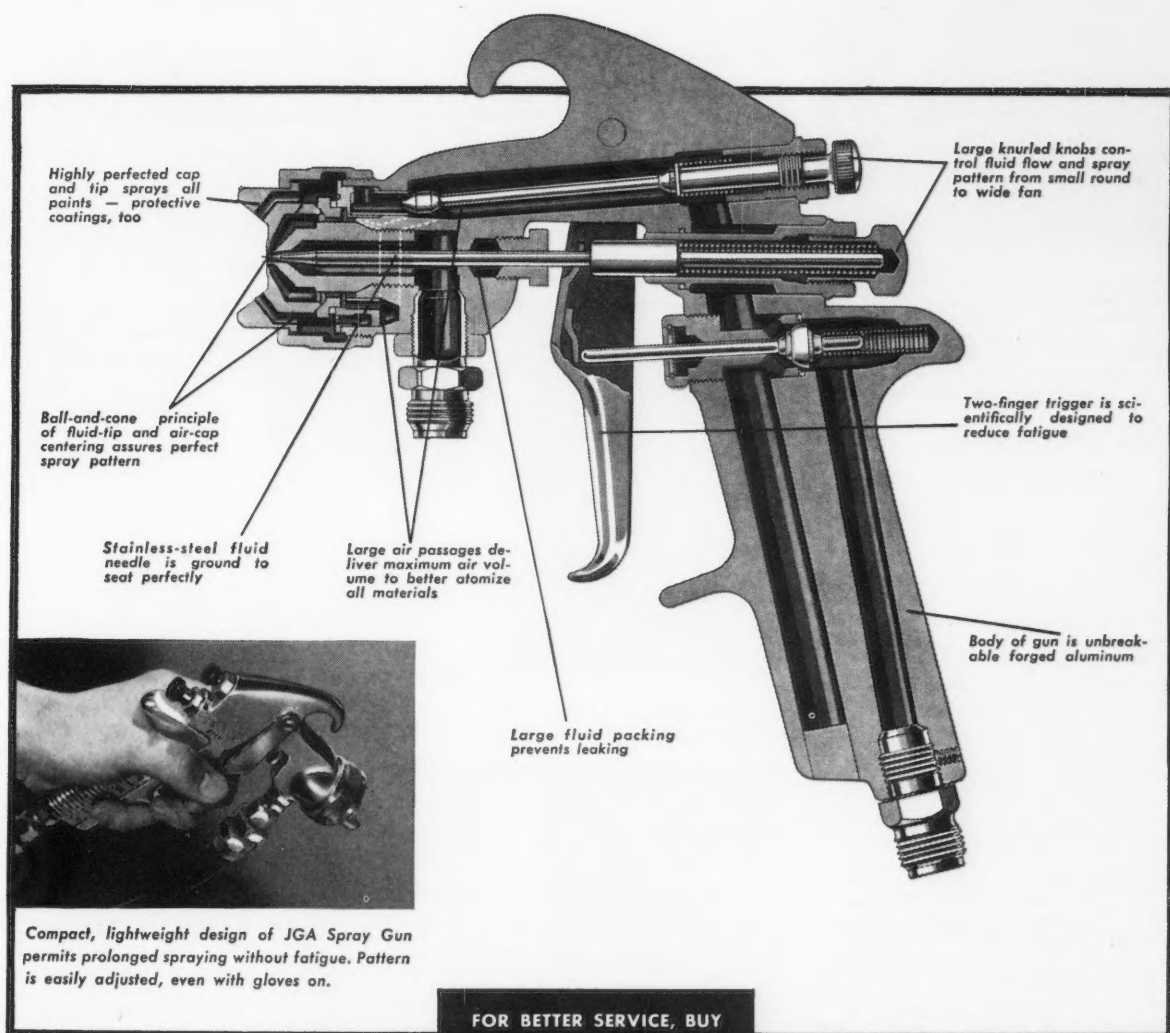
Figure 3—Variation in polyester structure.

* Presented under the title "Urethane Coatings" by Richard C. Bueck, Mobay Chemical Company, St. Louis, Mo., at the 13th Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., March 11-15, 1957.

⁽¹⁾ Mobay Chemical Company has tradenamed its isocyanates "Mondur" and its special polyesters "Multon" resins.

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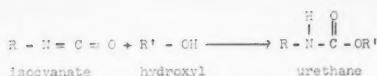


Figure 4—Reaction producing urethane.

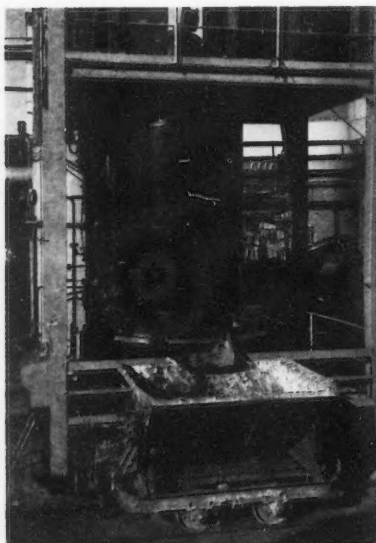


Figure 5—A water gas generator in the Farbenfabriken Bayer plant in Germany six years after coating with urethane. Unit is subject to corrosive gases, expansion resulting from temperature range between freezing and 250 F. While showing brittleness and loss of gloss, no metal corrosion occurred.

Urethane Coatings—

(Continued From Page 130)

mine the properties of a urethane coating are types of isocyanate and polyester, ratio of isocyanate groups to hydroxyl group and type of cure.

By proper selection of the polyester resin and by increasing or decreasing the amount of isocyanate, properties of the urethane coating can be varied from extreme flexibility to permit use over rubber to extreme hardness to give corrosion resistant maintenance coatings. The more linear the polyester, the more flexible the resulting film; the more highly branched, the harder and the more chemically resistant the film. One and two-part coatings can be formulated.

Urethane coatings have been used in Germany as maintenance coatings in steel mills to coat practically everything including blast furnaces. These coatings are used in steel forging shops, chemical plants, slaughter houses, dairies and breweries, where they are subjected to continuous moisture and cleaning processes. They are used also in conveyor systems where this high impact and abrasion resistance has proved them exceptional as room temperature cured coatings. They are used extensively as both wood and concrete floor coatings.

Urethane coatings also have been used in Europe as coatings for the interiors of vats containing potable juices and cognac and in beer kegs.

High gloss associated with urethane

coatings will be dulled in pigmented formulations subjected to outside exposure and white or pastel shades exposed to ultra violet will have a tendency to yellow. Loss of gloss can be lessened by using low pigment concentrate in top or surface coats. Non-pigmented clear coatings retain their full gloss on aging.

Commercial quantities of Mondur CB, an isocyanate adduct containing less than 1 percent free tolylene diisocyanate monomer are available now. This coating requires no precautions additional to those normally used in handling coatings incorporating solvents. This new material was developed to supersede Mondur C, which contains a free isocyanate monomer which is irritating in sufficient concentration. While this component is non-toxic it did impose the necessity for added protection for workmen handling the material.

DISCUSSIONS

Questions by Frederick Terman, General Services Administration, Washington 25, D. C.:

In relation to the costs of maintenance painting, for instance with old corroded steel hot water generating tanks that we are trying to keep in operating condition, "What would be the costs involved for this urethane coating system

as compared with phenolic resin, epoxy, and cementitious coatings applied on the job?" I am particularly interested in the costs also of surface preparation, number of coats and relative safety of application of these coatings in comparison with urethane systems.

Reply by Richard C. Burck:

Paint manufacturers now marketing urethane coatings as standard products are charging prices competitive to the better maintenance coatings. In corrosive atmospheres surface preparation recommended includes sand blasting for best coating performance. The better urethane coating systems can be applied in a three coat build to obtain a 5 mil film. There are no hazards involved in the application of urethane coatings when Mondur CB is used as the isocyanate component; the only precautions required are therefore normally observed in handling paints formulated with solvents which, in the case of urethanes, usually include cellosolve acetate, toluene and xylene.

Questions by Stanley L. Lopata, St. Louis, Mo.:

1. What is the maximum relative humidity at which polyurethane coatings based on Mondur CB can be applied?

(Continued on Page 138)

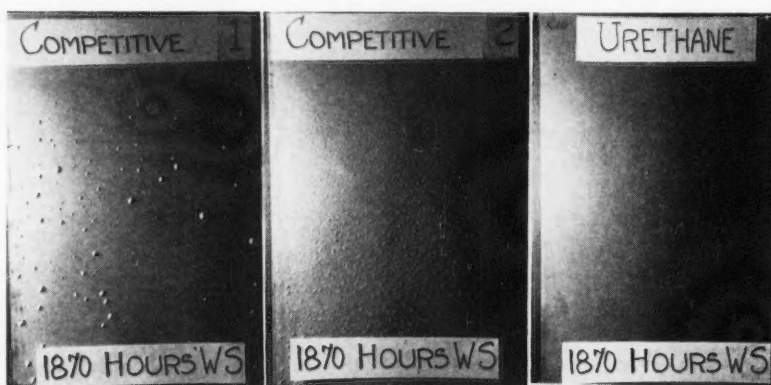
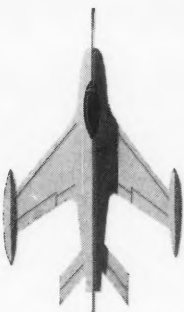
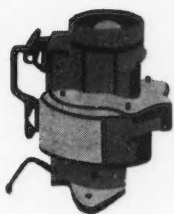


Figure 7—Results of laboratory tests on 6 x 9 inch metal panels coated with (left to right) competitive coatings, panels 1 and 2 and urethane, panel 3 after 1870 hours submerged in water.



Figure 8—Results of tests on coated panels. Indicated solvents were placed on panel and covered with glass squares for five minutes. Squares were removed and panel wiped dry. Competitive 1: All agents except 50% acetic acid softened the coating. Competitive 2: Methylene chloride and phenol had worst effect. Urethane: 85% phenol in ethyl alcohol softened coating so it could be scratched. (All panel tests by E. R. Wells, Mobay Chemical Co., Research Laboratories.)

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Some Keys to Successful Industrial Contract Painting*

Establishing a Painting Program

A SEPARATE department, division of a department or an individual, with the corrosion engineer either directly in charge or as the right hand advisor to the person in charge is a prerequisite to a well organized painting program. This agency should establish a long range plan of protection and appearance. Basic in a successful painting program are:

1. Study of the environment and exposure.
2. Use of proper surface preparation.
3. Selection of the proper material.
4. Proper application of the material.
5. A continuous maintenance program.

A schedule of maintenance and appearance painting requirements by individual areas should be projected to serve as the foundation on which the program is constructed.

Paint systems will be determined by the environments in which the coatings must perform. Generally a basic system will be evolved with specialized systems for troublesome areas.

Selection of these systems will be the responsibility of the corrosion engineer, who considers recommendations of paint manufacturers, information gained through publications and work of organizations such as the National Association of Corrosion Engineers and results of test programs. Many costly errors have been made in paint testing programs by selecting a material solely on performance of a 3-inch square panel in a field test. Small panels are fine for initial testing but it is strongly recommended that a field test with a minimum of 500 square feet in the area to be painted be used as final criterion.

Specifications Should Be Realistic

General painting specifications for all contract work should include:

1. Standards of surface preparation in each category:
Sandblasting, hand cleaning, pneumatic tool cleaning, etc.
2. Standards of paint application covering brushing, spraying (cold and hot), roller application, etc.
3. Standards defining inspection methods and equipment to be used.
4. General conditions covering plant rules, safety, working hours and other requirements.

Each contract job needs individual specifications referring to portions of the general painting specifications which are applicable. Detailed additional requirements called for by the particular job should be added, including surface preparation, the number of coats and color schemes.

Specify precisely what is to be done, tell bidders what is wanted and then see that precisely what the specifications

call for is delivered. Many contractors have lost bids solely because they bid in accordance with specifications only to see the work completed by another contractor, who, not only didn't follow specifications, but did not intend to follow them to start with.

Contractors often are severely abused because of unreasonable inspection and many owners have lost large sums of money because of inefficient inspection or an improperly qualified inspector. The owner's paint inspector should be selected with great care. Knowledge of the practical side of painting, preferably from first hand experience, as well as technical training are mandatory qualifications.

Specifications should not tell the contractor what to produce as a finished result and at the same time tell him exactly how to accomplish the result. For example, on a sandblasting job stipulate the type of surface desired but do not tell the contractor what size nozzle, hose, air pressure, etc., he must use. In so doing ingenuity, initiative and progress are stifled and frequently costs are greater because the desired result often can be obtained with different equipment combinations at a lower cost.

For a price survey or estimate to determine budget requirements ask for a preliminary figure. This will save preparing a firm lump sum quotation, an expensive operation for a contractor. As an example, on a recent \$200,000 job, cost of preparing a bid was over \$1100.

State accurately when a job is to start and specify completion time, if any, bearing in mind that such requirements affect a contractor's price.

Allow a reasonable time for the contractor to prepare an intelligent bid.

All bidders should be notified when the job is awarded.

Plan contract work during the most favorable weather conditions. Don't paint tank farms in December and hot interiors of power house in July. Plan jobs so they will have continuity. Frequently a contractor will finish a job and lay off a well-trained crew only to find two weeks later that another job is to be done.

How to Take Bids

Consider a so-called "show date" so contractors bidding on a job may have representative see the job site. This will assure all bidders receiving the same instructions and information. In addition have all plant people directly concerned with the work present at the "show date." Define the scope of work and the intent of the specifications clearly to all. Where there is any doubt on a given point, for example, the degree of surface preparation desired, then have a field example or demonstration to clarify it.

Choose responsible contractors by checking backgrounds as to experience, past performance and integrity. Obtain from them a list of clients for whom they have performed similar work and check these references thoroughly. By

Abstract

Successful use of the services of an industrial contract painter involves establishment of a painting program, compilation of specifications, a bidding procedure which gives all an equal chance to get the work, care in selecting a responsible contractor, thorough inspection to assure specifications are met. Manufacturers are advised to keep sales people informed adequately on technical matters, provide application instructions to the men doing the actual work, and have technical representatives inspect jobs in progress to check on failure to follow recommendations. The contractor should be willing to stay abreast of new equipment and materials, train his workmen properly and provide competent field supervision.

such reference checking many plants who have had six, eight or more bidders will discover there are not that many qualified contractors in a given area. In other words, settle on three or four competent bidders to get realistic prices and a better quality job.

Analyze Bids Carefully

If quotations vary widely something is wrong. A bid which is too low may cause trouble.

Many plants are now doing maintenance painting on a cost-plus basis and these plants know these same principles apply to comparisons of contractor's fees on cost-plus proposals. It is not how low the fee is but rather what is received for the fee in performance that counts.

Knowledgeable Paint Salesmen Needed

Coatings now are formulated and produced for every exposure and environment. There is a great need, however, for the technical knowledge assembled in laboratories to be transmitted to sales divisions of manufacturers. High pressure or "sales manual" type salesmen in the industrial field are outmoded because in many cases the salesman now must deal with an engineer or chemist and not just a buyer.

One of the most needed services does not begin until the paint is sold and delivered. This is the presence of a technical representative in the field when the job is started and on periodical visits to service it until it is completed. This representative should know whether his material is being applied properly and be able not only to say how to apply but to put on work clothes and show how it should be done.

A shortcoming of many material suppliers is their failure to give application instructions on their material to those who should have them. No one application technique is adaptable to all paint materials and without proper application any material is doomed to fail. Literature and application instructions seem to get no further than the purchasing agent or a corrosion engineer, when the superintendent or foreman and the man to apply it also should receive detailed information. In addition to this distribution of literature it certainly would be conducive to good application to reduce the size of the manufacturer's name on the paint can labels to allow sufficient room for complete instructions to be printed on each container. It is a source of amusement

(Continued on Page 136)

*Condensation of a paper presented under the title "An Industrial Painting Contractor Sounds Off," by L. L. Sline, Sline Industrial Painters, Houston at the 13th Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo. March 11-15, 1957.



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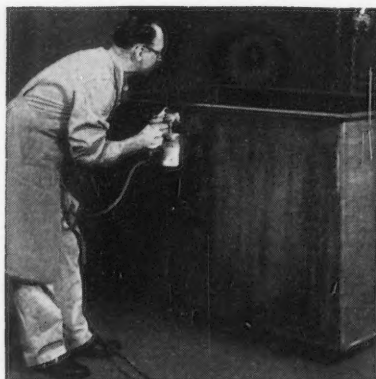
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Some Keys to—

(Continued From Page 134)

among contractors that one can go to a five and ten cent store and buy a 20c can of enamel which has more instructions on the label than an \$8 per gallon can of industrial paint.

Conditions Are Not Detailed

Many manufacturers give detailed instructions on both application technique and equipment requirements for their materials but by not listing the conditions under which these standards were determined they cause voluminous problems in the field. Some specifications undoubtedly have been prepared carefully in a laboratory test with ideal conditions and with a temperature of 70 degrees, controlled humidity and no weather disturbances. In the field they will not necessarily produce good results because many problems are encountered there which do not exist in the laboratory.

In the Southwest frequently the mornings start with a 40 degree temperature, which by noon rises to 60 degrees and by afternoon reaches 70 degrees. This affects viscosity and as a result working pressures must be adjusted. Height of work, size and shape of facilities being painted and even geographical location across the country all are capable of creating conditions under which laboratory specifications, if strictly adhered to, will not produce good results.

A realistic estimate of square foot coverage for field application would be immediately and gratefully adopted by all concerned with industrial painting.

Industrial Painting Contractor

Paint contracting in the industrial field is a very specialized business. It is no place for even the most experienced residential and commercial painting contractor. Likewise, it is no place for an industrial painting contractor, who, although already in the business, is not willing to stay abreast of the times. The successful contractor must know about developments in materials and equipment. This knowledge involves seeking supplier's representatives to learn of new coatings, what they will do, how to apply them and reviewing new equipment developments. Field tests should be made on products which show promise.

Training programs for foremen and key journeymen are essential. Many material and equipment manufacturers have instructors and schools. Some courses, such as spray painting schools, involve a substantial fee but will return many dividends.

High calibre field supervision is necessary. Large industrial jobs require a superintendent who has the jack of all trades quality. Not only must he have the background in the practical side, a basic technical knowledge of corrosion and protective coatings, but also the ability to deal with the client's representatives, maintenance superintendent, corrosion engineer or inspector on the day-to-day aspects of the job.

DISCUSSIONS

Question by Tom M. Andrews, Union Carbide Nuclear Co., Oak Ridge Tenn.:

My request was for data on fluorocarbon coatings. F. M. Ruggles and Leo J.

Fitzharris of The W. M. Kellogg Co. let me have data on Kel F coatings which may be sprayed on and baked. One experienced concern in coating process vessels for resistance to nitric acid, aqua regia and hydrofluoric acid is Silicone of Indiana, Inc., 4502 N. Keystone Ave., Indianapolis, Indiana, as per conversation with plant manager, Mr. Neal Benson. I understand that this process has only been in use approximately 18 months, but has been proven satisfactory.

Additional information on similar fluorocarbon coatings would be of interest to many people handling aqua regia and hydrofluoric acid.

It would be highly desirable to have such a coating not requiring a baking oven in order that it might be used on structural steel which is already in place.

Reply by L. L. Sline:

I have no data on these materials.

Question by Ross Bacon; Dow Chemical Co., Freeport, Texas:

You mentioned about .5% cost for preparing a bid. Can this be considered the average cost of preparation of bids?

Reply by L. L. Sline:

The example quoted was a particular job experience and not an average. Cost of preparing a bid depends upon the time and expense required and this is determined by whether it might be a complicated blue print take-off or a simple field take-off, size of the job, travel expense required, etc. If anything 1/2 of 1% of the bid is below the average.

Question by E. G. Brink, American Viscose Corp., Marcus Hook, Pa.

To what extent do you find it practical to include a pinhole detection test in a painting specification, particularly from the cost standpoint? By what percentage does such a test increase the cost of a job?

Reply by L. L. Sline:

This is a difficult question to answer briefly. Assuming that a quality material is being applied by skilled mechanics a pinhole detection test would not generally be practical, for it will increase your cost, except in severe corrosive areas. When such a test is required the cost would vary greatly depending upon the strictness of the test, with a 100% pinhole free requirement increasing cost substantially.

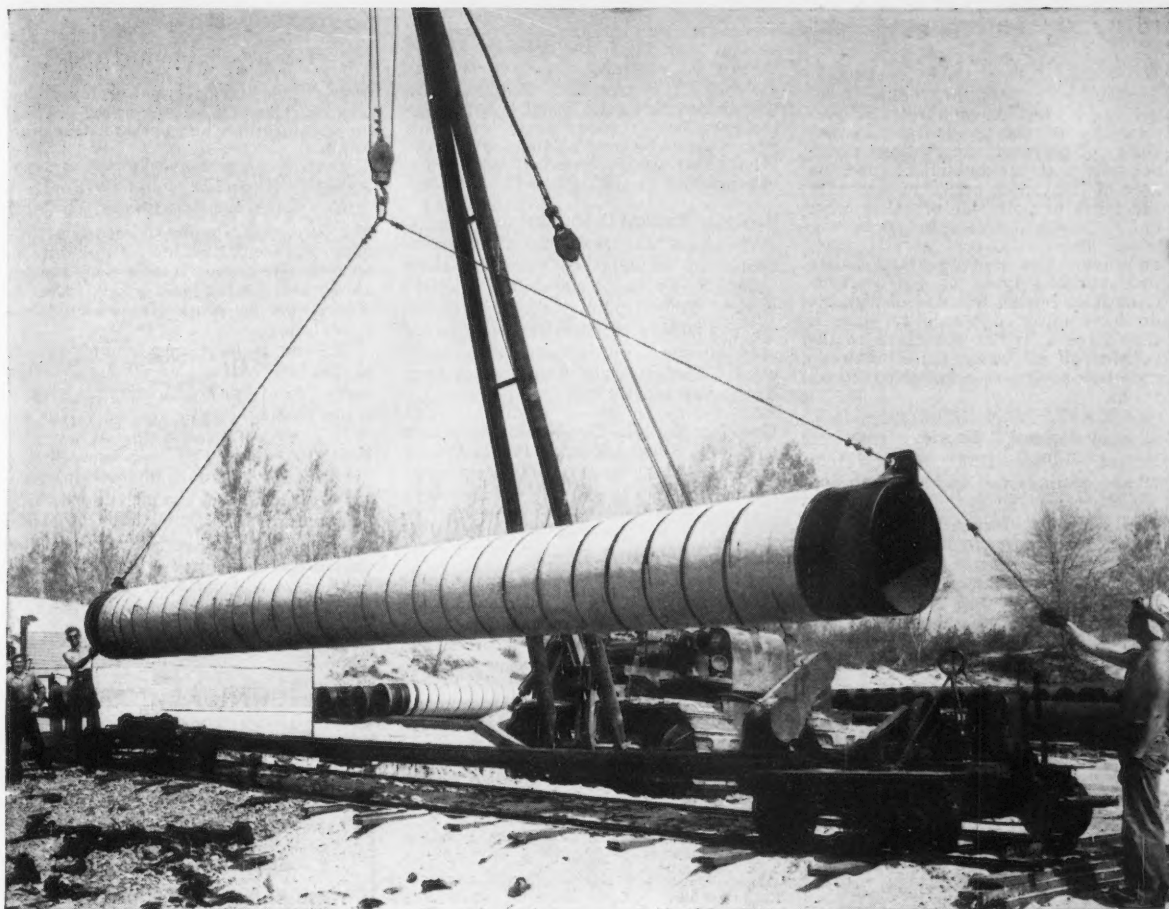
Question by J. J. Bigos, U. S. Steel Corp., Monroeville, Pa.

The views expressed in your paper are progressive and—if adopted universally—should lead to considerable upgrading of the work done in the industrial maintenance painting field. Can you tell us how to protect ourselves against unscrupulous painting contractors who have set a low price and are determined to sacrifice quality to meet their low bid?

Reply by L. L. Sline:

The following four part procedure is offered: 1. Screen your bidders so that only reputable contractors are on the bidders list. 2. Eliminate a bid which is obviously too low for the projected work. 3. Have a clear and complete con-

(Continued on Page 138)



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Urethane Coatings—

(Continued From Page 132)

2. The following was the comment regarding a question on the water permeability of polyurethanes: "Permeability of polyurethane coatings varies not only with the amount of cure, the type of isocyanate used, but also with the types of polyester or other cross linking material. Work in our laboratories during the past several years on polyurethane materials have shown that certain types of polyurethane cross-linked with toluol di-isocyanate do have lower permeability; that is they have a higher resistance to the penetration of water vapor than do room-temperature amine-cured epoxy resins.

Replies by Richard C. Burck:

Recent findings have shown that urethane coatings can be applied to any dry surface under any humidity condition. The only precaution required is that surfaces exposed to outdoor weather must be protected from rainfall for at least four hours following application of coating.

Question by C. J. McBride, Houston:

Since film permeability is a very important aspect of an organic coating barrier, do you have any data on comparison of the urethane coating under discussion with such baked coatings as the phenolics or epoxy-phenolics? Have you evaluated these coatings using the Payne Permeability cup test method for unsupported films?

Reply by Richard C. Burck:

We have not evaluated the permeability of unsupported urethane films using the Payne Permeability cup test method. Actual permeability figures are not available. Comparative performance data however, do indicate that highly cross linked urethane films have a very low permeability.

Question by E. G. Brink, American Viscose Corp., Marcus Hook, Pa.

After the addition of the catalyst what is the working or pot life of the polyurethane coatings?

Reply by Richard C. Burck:

After addition of the isocyanate component the work life of a urethane coating will vary between 8 and 36 hours depending on the degree of branching in the polyester used. The better corrosion resistant coatings, formulated with highly branched polyesters, will have an average work life of 8 hours unless exposed to very high temperatures, in which case work life will be reduced to 4 to 6 hours.

Question by Clifford L. Dotson, Youngstown, Ohio:

What surface preparation and application techniques are used for urethane coatings?

Reply by Richard C. Burck:

Surface preparation is covered in No. 1 above. Application is accomplished by the normal spray or brush method.

Some Keys to—

(Continued From Page 136)

tract drawn and executed, 4. By means of your inspector and engineer see that the specifications and contract terms are fulfilled.

Paul J. Gegner, Columbia-Southern Chemical Corp., Barborton, Ohio:

You say that a paint company's technical representative should not only be able to tell a contractor's men how to apply his coating but should also be able to put on work clothes and show them how.

Do you really expect paint salesmen to put on coveralls and show skilled spray painters, for instance, how to apply coatings?

Reply by L. L. Sline:

I certainly do recommend the paint salesman being qualified to actually demonstrate the application of his own material. Our experience has shown that skilled mechanics are quite receptive to instruction and particularly if a material has unusual spraying characteristics.



TECHNICAL REPORTS

on

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T-5A-4 A Bibliography on Corrosion by Chlorine. A Report of Technical Unit Committee T-5A on Corrosion in the Chemical Manufacturing Industry. (Compiled by Task Group T-5A-4 on Chlorine.) Pub. 56-2. Per Copy \$1.50.

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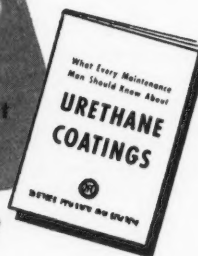
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CORROSION ABSTRACTS

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Vol. 13 December, 1957 No. 12

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4. CORROSIVE ENVIRONMENTS

4.3 Chemicals, Inorganic

4.3.2, 5.8.3, 6.2.3

Effect of Certain Organic Compounds on the Solubility Ratio of Carbon Steel in Inorganic Acids. (In Russian.) S. A. BALEZIN AND M. A. IGNAT'YEV. *Doklady Akad. Nauk SSSR*, 109, No. 4, 771-773 (1956) August 1.

Effect of inhibitors on corrosion of steel in sulphuric and hydrochloric acids.—MR. 13498

4.3.3, 3.5.9

On High-Temperature Corrosion of Metals by Vanadium Dioxide. I. Research on System Metal-Vanadium-Oxygen. (In Italian.) V. CIRILLI, A. BURDESE AND C. BRISI. *Metallurgia Italiana*, 48, No. 7, 309-316 (1956) July.

Equilibrium diagrams between vanadium dioxide and iron, chromium, nickel and cobalt peroxides.—MR. 13566

4.6 Water and Steam

4.6.2, 3.5.8, 6.2.5

Stress Corrosion Tests of Stainless Steels in High Temperature Waters. R. B. NIEDERBERGER. Naval Engineering

Experiment Station, Annapolis, Maryland, Rept. EES-040028M, Feb. 15, 1956, 17 pp.

Laboratory stress corrosion tests, using U-bend specimens exposed in the liquid and vapor phases of chloride bearing boiler water at 500F, have been conducted with Type 304 stainless steel, stress relieved at 900F and at 1700F after preparation of specimens, Type 430 stainless steel, Carpenter 7 molybdenum steel, and with a group of 6 austenitic steels containing nickel in amounts ranging from 10 to 40%. Stress corrosion cracking occurred in vapor exposed specimens of all materials except Type 430 stainless steel. The results confirm the conclusion that austenitic stainless steels as a class are subject to stress corrosion cracking in high temperature waters containing chloride and oxygen. (auth.)—NSA. 13683

4.6.2, 3.5.8, 6.2.5

Stress-Corrosion Cracking of Austenitic Stainless Steels in Low Pressure Steam and Hot Water. S. BRENNERT AND H. NATHORST. *Jernkontorets Annaler*, 140, No. 11, 839-853 (1956).

Reports of experiments on 18/8 molybdenum steel showing that stress-corrosion caused by low pressure steam and hot water is due to stresses of sufficient magnitude, oxygen and conditions such that hot, strong chloride solution is formed.—INCO. 13532

4.6.2, 5.7.3

Oxygen Scavenger Combats Boiler Tube Corrosion. A. J. FRIEDSAM AND E. R. WOODARD. *Heating, Piping, Air Conditioning*, 29, No. 1, 164-165 (1957) Jan.

Acidity and dissolved oxygen in boiler

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Ku, Tokyo, Japan.

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NSA—Nuclear Science Abstracts, United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tennessee.

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RPI—Review of Current Literature Relating to the Paint Colour, Varnish and Allied Industries, Research Assoc. of British Paint, Colour and Varnish Manufacturers, Paint Research Station, Waldegrave Rd., Teddington, Middlesex, England.

SE—Stahl und Eisen, Verlag Stahleisen, m.b.H., Breite Strasse 27 (Schliessfach 2590), Düsseldorf, Germany.

TIME—Transactions of The Institute of Marine Engineers, The Memorial Bldg., 76 Mark Lane, London E. C. 3, England.

ZDA—ZDA Abstracts, Zinc Development Association, 34 Berkeley Square, London W. 1, England.

feedwater are major causes of metallic corrosion in heat generating systems. Experience shows that best safeguard against acidic corrosion is maintenance of pH values at 10-11. Description of chemical treatment of boiler feedwater by addition of hydrazine hydrate in heating boiler installation in a large apartment project is given. Photos.—INCO. 13764

4.6.4, 3.3.4

Cooling Water Treatment: A Review. M. BROOKE. Phillips Petroleum Co. *Petroleum Refiner*, 36, No. 2, 142-148 (1957) Feb.

Review covers prevention of scale formation by external treatment (lime-soda and ion exchange softening) and internal treatment (lowering pH with acid and

sequestering with chelating agent), prevention of corrosion of metal in contact with cooling water by controlled scale and use of corrosion inhibitors, prevention of fouling of cooling surfaces and cooling tower by algae control and slip-stream filtration and prevention of deterioration of cooling tower lumber. Chart identifies bacteria, algae and fungi found in recirculating cooling water. Chemicals used to combat biological growths include copper salts, mercury compounds, potassium permanganate, quarternary ammonium compounds, phenolic compounds, chlorine and bromine. Tables, graphs, 20 references.—INCO. 13761

4.6.6, 3.4.3

Findings on the Chemical Activity of Water and the Composition of the Prod-

ucts of Incrustation and Corrosion. (In French.) T. SAMUEL. *Revue Technique Luxembourgeoise*, No. 4, 205-207 (1956) Oct.-Dec.

Chemical nature of the several types of corrosion in water mains; inhibiting factors and methods of prevention.—MR 13666

4.6.7, 2.2.7

Corrosion of Steel Pipe by Savannah River Water. FRED WELTY. E. I. du Pont de Nemours & Co. U. S. Atomic Energy Commission Publ., DP-170, August, 1956 15 pp.

Test sections of carbon steel pipe were pitted to a maximum depth of 0.06-in. during 30 months of exposure to flow of raw river water.—BTR. 13698

4.6.10, 5.4.8

Missouri Pacific (Railroad) Brine Drippings Test. Steel Structures Painting Council. Steel Structures Painting Bull., 2, No. 1, 5, 7 (1956).

Findings of the test designed to evaluate paint systems on two river bridges are reported. The bridge which had been sandblasted continues to be in almost perfect condition. The only breakdown occurred on a neoprene coating. This is attributed to poor procedures noted at the time of application. On the second bridge, which had been prepared by chipping, scraping, wire-brushing and steam cleaning, in some vital areas where brine contact was continuous and cleaning probably inadequate, considerable breakdown occurred. The system with red lead and linseed oil primer with litharge added and phenolic intermediate and topcoats rated best, with a wash primer, red lead/vinyl and aluminum/vinyl topcoat system close behind. The performance of rust-preventive compounds and an asphalt oil coating with bridge cement topcoat was found to be very unsatisfactory.—RPI. 13653

4.6.11, 3.2.2, 8.9.5, 3.3.1

Pitting Corrosion of Reserve Fleet Ships. E. F. CORCORAN AND J. S. KITTREDGE. Paper before Marine Corrosion & Fouling Conf., Scripps Inst. Oceanography, La Jolla, California. *Corrosion Prevention & Control*, 3, No. 12, 45-48 (1956) Dec.

Inactivated ships in San Diego Bay are being heavily damaged by intense pitting corrosion of their plates. Chlorinity determinations and drift spar measurements indicate transport of sewage as surface layer into fleet area. Extreme degree of oxygen supersaturation and high concentrations of organic carbon exist in surface waters. Phytoplankton counts reveal presence of large population of photosynthetic organisms. Sulfate-reducing bacteria exist in inner layers of organic slime and corrosion products on water side of ships' plating and corrosion nodes leading to pits contain ferrous sulfide. Mechanism is electrochemical corrosion in oxygen concentration cells created by rapid bacterial oxidation of organic matter absorbed to plating.—INCO. 13557

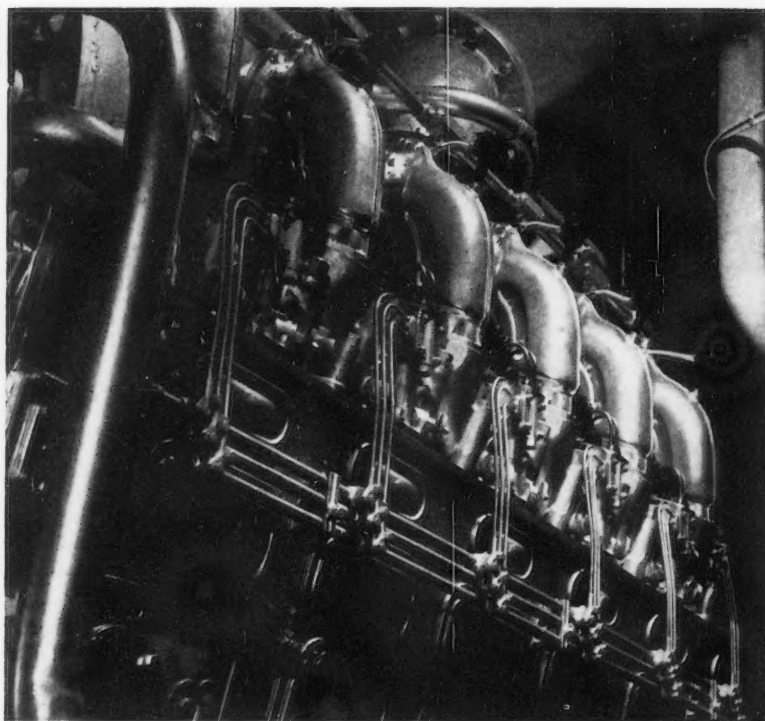
5. PREVENTIVE MEASURES

5.4 Non-Metallic Coatings and Paints

5.4.3, 5.3.2

Protective Lining Systems. R. A. MIXER AND S. J. OECHSLE. *Chem. Eng.*, 63, No. 11, 176-196 (1956).

Linings, as defined by the article, pro-



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test containers from corrosion by the substance within, or protect the substance from contamination by the container. Those in general use are based on metals, on rubber or on synthetic resins. The economics of their use are described in detail.—RPI. 13692

5.4.5, 5.3.2

Painting of Galvanized Steel. H. W. CHATFIELD. *Paint, Oil, Colour J.*, 131, 530-434 (1957) Feb. 22.

Calcium plumbate with waterground mica added shows advantages over red lead. Baked primers improve adhesion. Results of natural weathering tests are given.—MR. 13782

5.4.5, 5.4.6, 4.5.1

Coal Tar Coatings for Protection of Underground Structures. NORMAN T. SHIDLER. *Corrosion*, 13, No. 6, 392t-396t (1957) June.

The history of the use of coal tar coatings for the protection of underground structures is discussed briefly. Specifications are given for the following hot applied coatings: Narrow range enamel, moderate range enamel, wide range enamel, AWWA enamel C 203-4 and hot pipeline enamel. Temperature ranges at which these coatings can best be used are shown graphically. Recommendations are made regarding the selection of a coating for a given underground condition.

Specifications are given for a cold applied coal tar coating which has been used successfully by the Bureau of Yards and Docks and by the Bureau of Reclamation. The coating has a variety of names in industry and is a thick, almost non-flowing, thixotropic material produced basically from a coal digestion pitch. 13707

5.4.5, 8.9.1

Catalyst Spraying Applied to Painting Jet Airplanes. D. M. GOLDING. *Ind. Finishing*, 33, No. 1, 28-30, 32, 34, 40, 42 (1956).

The entire surface is degreased with methyl ethyl ketone and rinsed with detergent, etching solution and water. This is followed by a brush-applied phosphating solution and rinse. The process is repeated after thirty days. The surface is then sprayed with a polyvinyl acetate/polyvinyl butyrate/phosphoric acid wash primer, the mixture comprising 4 pt. resin to 1 pt. acid (catalyst). This is followed by a sprayed zinc chrome coating. The finish comprises two coats of an acrylic resin. The importance of correct viscosity of the spray formulations is stressed.—RPI. 13607

5.4.5

Observations on Phosphating Primers. R. BOURBON AND J. J. M. DE PAULIN. *Corrosion et Anti-Corrosion*, 4, No. 3, 90-96 (1956); *Paint. Ind. Res. Inst. Lit. Digest*, 7, No. 2, 44 (1956).

Wash primers, both two-package and ready for use, have been studied. Some remarkable results have been obtained on outside exposure of primed panels without finishing coats. Very dilute primers give too thin a coating and will neither adhere nor resist exposure, irrespective of the top coats. Several of these primers adhere well to certain alloys but very badly to degreased aluminum. It is stressed that the conditions

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of application, drying and aging may have a profound effect on the performance of these primers.—RPI. 13515

5.4.5

Organic Polyisocyanates: Their Use in the Surface-Coatings Industry. H. A. HAMPTON AND R. HURD. *J. Oil Colour Chemists' Assoc.*, 39, 609-622 (1956) August. 13604

5.4.5

Coatings Based on Blends of Polyamide and Epoxy Resins. DAVID GLASER, DON FLOYD AND HAROLD WITTCOFF. *Official Digest Federation of Paint and Varnish Production Clubs*, 29, 159-169 (1957) Feb.

Films dry quickly, are hard, glossy,

decorative, flexible and have good adhesion. They have good resistance to alkalis, acids, boiling water, aliphatic hydrocarbons and oils.—BTR. 13744

5.4.5

Plastics and the Corrosion of Iron and Steel. G. A. CURSON. *Corrosion Technology*, 4, No. 3, 79-82 (1957) March.

Describes methods of application, properties of coatings and their uses in industry for coatings of polythene, nylon, thiokol, shellac, Araldite (epoxide resin) and Epikote. Application methods include dip-coating, flame-spraying, oven technique and fluidizing process.—INCO. 13753

5.4.5

Silicones and Their Application in Protective Coatings. H. L. CAHN. *Official Digest Federation Paint and Varnish Production Clubs*, 28, No. 378, 590-602 (1956) July.

The author gives a short account of the chemistry and manufacture of silicones followed by a description of the formulation and properties of silicone resin coatings. These are said to have outstanding resistance to heat, mild chemicals and solvents including water. Zinc dust, aluminum flake, zinc oxide, lithopone and antimony oxide are considered to be suitable pigments and zinc yellow combined with red iron oxide has been found satisfactory. Zinc octoate and naphthenate are widely used as catalysts to accelerate the curing of the coating. Several typical paint formulations are given. The paper concludes with a discussion on silicones in water repellents for masonry.—ZDA. 13521

5.4.5, 2.3.7

Getting Painting Value by Scientific Control. R. B. KAVINOKY. *Eng. News Record*, 156, No. 1 52-56 (1956); *Building Sci. Abstr.*, 29, No. 9, 295 (1956).

Factors (such as exposure, surface preparation, choice and application of materials) affecting the efficient use of protective coatings to combat corrosion are discussed with special reference to scientific control for ensuring durability. The latter property is largely dependent on the thickness, adhesion and continuity of the applied coating. Tests on steel panels with simulated large-structure irregularities show that, for non-submerged structures, a minimum dry thickness of 0.005" on flat surfaces is necessary to give adequate protection to any welds and sharp edges. The coating thickness can be measured with a small magnetic gauge, while the on-site evaluation of adhesion can be done best with a pocket-knife. Correctly applied paint does not flake and the surface after abrasion with a knife is comparatively smooth. For thick coatings porosity is best detected by a high voltage spark tester and for thin coatings by determining the resistance when the paint and its substrate are included in a low-voltage electric circuit.—RPI. 13611

5.4.5

Wash-Out of Enamel Coat. K. F. SCHREIBER. *Ind. Finishing*, 32, No. 11, 36, 38, 40, 43-44 (1956).

"Wash-out", which may occur in connection with dipping, flow coating or spray painting, is a partial wash-off of freshly applied paint or enamel in some pocketed, shielded or semi-concealed area where excessive solvent vapor may concentrate or collect and act as a "remover" of the coating.—RPI. 13684

5.4.5

Wash Primer. G. MULLER, R. BOCK, K. HOFFMANN AND R. KREINHOFNER. *Angew. Chem.*, 68, No. 23, 746-752 (1956).

Wash primers based on zinc tetroxy-chromate, polyvinyl butyral and phosphoric acid are described. Satisfactory results are obtained on steel with a two-component primer mixed before use but with a single-component primer a reduction in adhesion occurs.—RPI. 13672

5.4.5, 7.7, 2.3.5

Stress-Cracking Corrosion with Isocyanate/Alkyd Lacquer Films. H. J. REISER AND F. GLANDER. *Farbe u. Lack*, 62, No. 8, 361-366 (1956).

A research is reported on the tenden-

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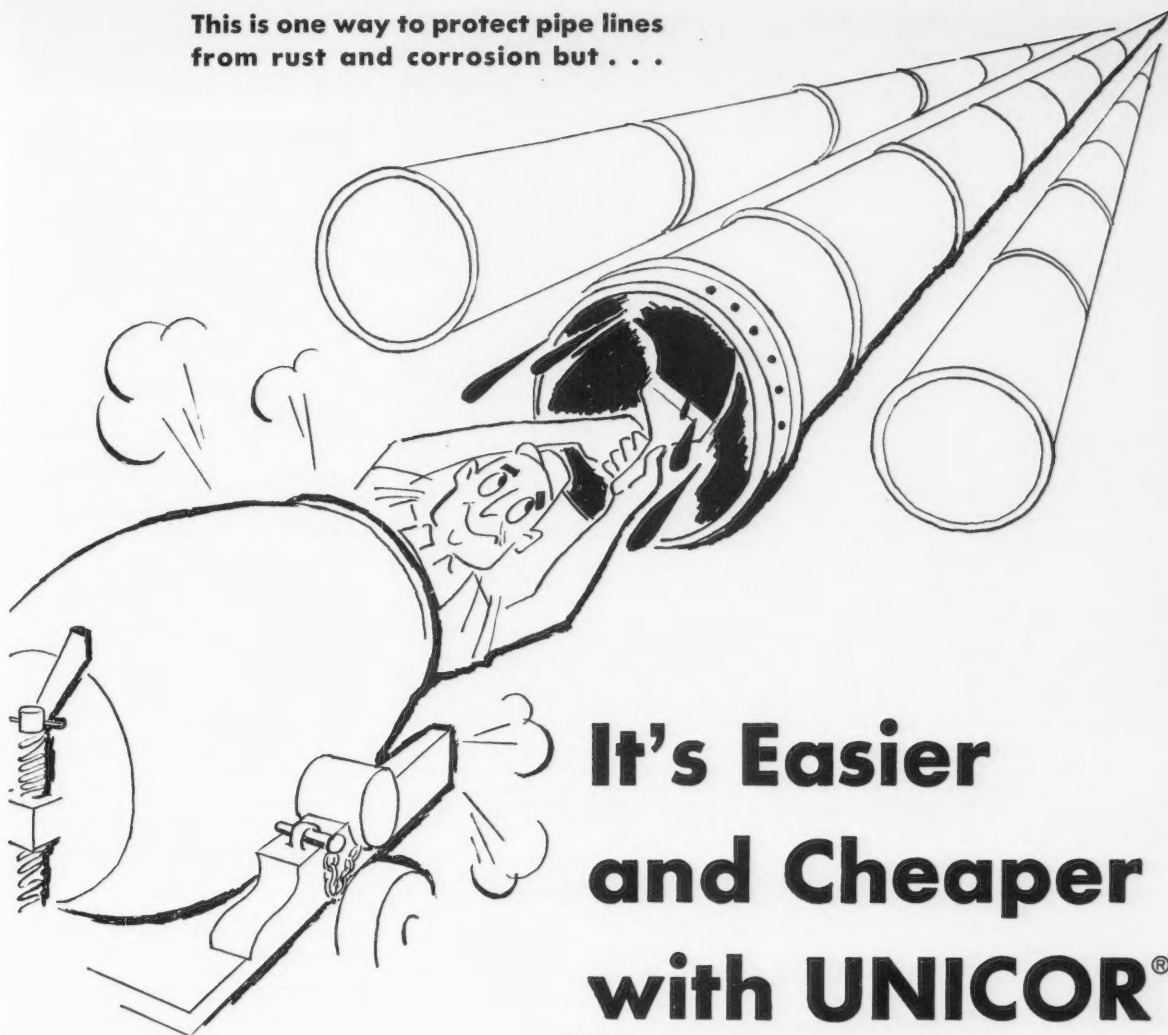


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cy to crack of isocyanate/alkyd wire coatings under tension in the presence of certain solvents and aqueous solutions. Preliminary data are quoted on the effectiveness of a range of solvents and solutions in promoting cracking at a standard wire extension and a more systematic study is presented, based on the extension required to produce cracking using electrical conduction through the coating under a 2 v potential as a measure of insulation breakdown; in particular, a detailed study is made of cracking in sodium chloride solutions. The effect of baking the lacquer at different temperatures is also reported. In general, the curve relating baking temperature to extension at breakdown rises to a peak extension between low values for low and very high temperatures. Cations are shown to influence the peak, e.g., the peak changes according to whether the wire is made anode, cathode or neutral. The cracking phenomenon is related to resin structure. The conventional 100 v insulation breakdown test is not applicable to isocyanate/alkyd coatings, since the test itself damages the lacquer.—RPI. 13673

5.4.7

Roller Application for Anti-Rust Paints. K. VAN OETEREN-PANHAUSER. *Duct. Farben-Z.*, 10, No. 1, 28-29 (1956). Experience with roller application of priming and other paints is discussed. In the shipbuilding industry, lamb's wool rollers are used, but Perlon is preferred in steel structure painting. Perlon is also favored when graphite paints are applied. Photographs show the different appearance of a red lead primer

and a wash applied both by brush and by roller, on glass.—RPI. 13706

5.4.8, 2.2.7, 8.9.5

New Means of Protection Against Corrosion of Metallic Ship Hulls. B. AGRANAT AND L. SUPRUN. *Morskoy Flot (Maritime Fleet)*, 16, No. 3, 21-23 (1956); *Chem. Abstr.*, 50, No. 16, 11212g (1956).

This is a report concerning the results of corrosion tests on 100 different types of protective coatings. The tests were standard laboratory corrosion tests and exposure in the sea (at Odessa) for two years. The object of the study was to select from available commercial paints and varnishes the best material for underwater protection of ships. The best results were achieved with paints of the divinylacetylene type with aluminum powder, with spirit varnishes pigmented with aluminum powder and with certain after-chlorinated polyvinyl chloride enamels.—RPI. 13489

5.4.8, 3.3.4, 2.3.3

How Research Is Preventing Fungus from Destroying Paint Films. J. F. LANG AND P. F. KLENS. *Can. Paint and Varnish Mag.*, 30, No. 2, 16-17, 32-38 (1956) Feb.

Most hard resins and alkyd media are said to be partly or completely inert to fungus growth while phenolic resins improve mildew resistance. Zinc oxide has a retarding effect in interior oil paints, most other pigments being inert. The hardness of the paint film, chalking, humidity of the atmosphere and weather conditions during painting are among the factors affecting the growth of fungus on paint films. Methods of testing

fungicides are described and the use of mercurials is recommended for both exterior and interior paints and copper 8-quinolinolate for interior paints.—ZDA. 13643

5.4.10, 7.2

Protection of Condensate Pipes Against Corrosion at Different Temperatures. Z. GRAAS AND J. SVACINA. *Chem. Prumysl.* 6, No. 11, 474-475 (1956).

Several experimental coatings were applied to iron pipes covered with sand at temperatures between 10 and 135°C. The best results were obtained with asphalt coatings covered with jute. Chloroprene foil applied over aluminum paint and glass fibre also gave adequate protection.—RPI. 13586

5.6 Packaging

5.6.1

Prevention of Corrosion in Packaging and Storage. Practical Methods of Preventing Corrosion in Packages. J. J. FERRIGLI. Paper before Soc. Chem. Ind., Symposium on Prevention of Corrosion in Packaging and Storage, Birmingham, April 11-12, 1956. *Chemistry and Industry*, No. 10, 280-287 (1957) March 9.

Discussion of packaging of corrodible articles for shipment overseas as to cleaning, drying, selection of and treatment with corrosion preventives, inner and outer packaging designed to prevent corrosion. Use of oil, solvent deposited strippable film, cocooning, paint and metallic coatings as corrosion preventives is described. Diagrams.—INCO. 13757

5.6.3

Temporary Protective Coatings. Part IV. Tape, Paper, and Wadding. E. STRONG. *Product Finishing*, 9, No. 5, 54-62, 126, 128 (1956).

Cellulose wadding and hard-resin solutions are considered. 13722

5.7 Treatment of Medium

5.7.3, 4.6.2

Comparison of the Reducing Power of Sodium Sulfite and Hydrazine in the Steam-Water Cycle of Steam Power Plants. F. G. STRAUB. *Univ. of Illinois. Combustion*, 28, No. 7, 34-39 (1957) January.

Describes and interprets series of tests conducted to determine reducing action of dilute solutions of hydrazine with the oxides of iron and copper and with low concentrations of dissolved oxygen. Reaction rates of hydrazine and sodium sulfite are compared under conditions existing in steam power plants. Formation of hydrazine from ammonia is discussed. Tables, graphs.—INCO. 13474

5.8 Inhibitors and Passivators

5.8.3, 3.6.5, 3.8.3

The Passivation of Iron by Osmium (VIII) Oxide and the Origin of the Flade Potential. G. H. CARTLEDGE. *Oak Ridge National Lab. J. Phys. Chem.*, 60, 1571-1575 (1956) November.

Osmium (VIII) oxide in dilute aqueous solution was found to raise electrolytic iron to a passive potential. The potential equaled the thermodynamic value for the Os (IV)-Os(VIII) couple

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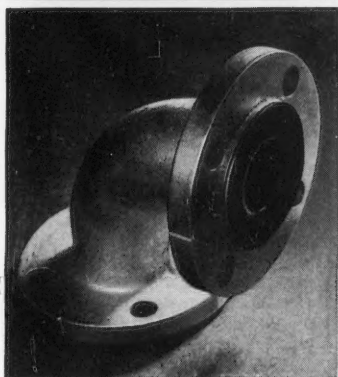
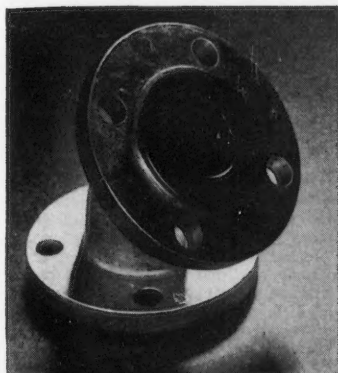
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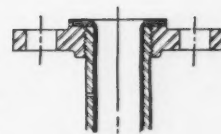
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under favorable circumstances, but was sensitive to the presence of sulfate and chloride ions of sufficient concentration. The results are discussed in connection with the mechanism of action of other XO_4^{2-} particles previously investigated and the nature of passive potentials.⁴ (auth).—NSA. 13541

5.8.3, 4.3.2, 6.3.19

Action of Some Organic Compounds on Acid Dissolution of Monocrystalline Zinc of High Purity. (In Italian.) L. CAVALLARO AND G. P. BOLOGNESI. *Metalurgia Italiana*, 48, No. 9, 393-400 (1956) Sept.

Effects of the "wetting" factor on the dissolution of the (0001) surface of zinc in presence of sulphuric acid. Inhibitors used included thiourea derivatives and some isosulphocyanates, together with ethyl alcohol.—MR. 13546

5.8.3, 3.6.5, 3.8.3

The Electrode Potential of the $\text{OsO}_2\text{-OsO}_4$ Couple. G. H. CARTLEDGE. Oak Ridge National Lab. *J. Phys. Chem.*, 60, 1468-1470 (1956) Oct.

The electrode potential of the osmium dioxide-osmium tetroxide (aqueous) couple at 24.5° is determined to be -0.964 ± 0.002 v. The data are of use in a study of the passivation of iron by osmium tetroxide.—NSA. 13606

5.8.3, 4.4.7

Study of the Mechanism of Action of Anticorrosive Additives in Oils with the Aid of Tracer Atoms. (In Russian.) YU. S. ZASLAVSKY, S. E. KREIN, R. N. SHNEEROVA AND G. I. SHOR. *Khimiya i Tekhnologiya Topliva*, No. 4, 37-49 (1956) April.

A study of the anticorrosive mechanism of alkyl-phenol additives tagged with radioactive sulfur. The protective action of anticorrosive additives is counteracted by the oil whose increasing acidity tends to destroy the protective film formed by the additive on the surface of the metal. Tables, graphs. 14 references.—MR. 13733

5.9 Treatment of Medium

5.9.1

The Pretreatment of Metal Surfaces. M. LEWIS. *Sheet Metal Inds.*, 33, No. 353, 639-646 (1956) Sept.

The article begins with a discussion on the necessity of treating a metal surface before painting and outlines the methods which can be employed. The importance of cleaning and various cleaning methods are discussed briefly. Parkerizing is considered in outline and Bonderizing in more detail. The advantages of solutions based on zinc phosphate are stated.—ZDA. 13636

5.9.2

Investigations on the Pickling Process. (In German.) WERNER LUEG, WINFRID DAHL AND HANS-JUERGEN ENGEL. *Stahl und Eisen*, 76, 1678-1685 (1956) Dec. 13.

Materials tested and testing methods, pickling tests on hot rolled strip in sulphuric acid, on samples with scale formed during annealing in sulphuric acid and hot-rolled strip in hydrochloric acid, in a mixed acid solution, subsequent treatment by prestressing, and conclusions. 5 references.—MR. 13616

5.9.2, 6.3.15, 3.2.2

Hydrogen Contamination in Descaling and Acid Pickling of Titanium (and Titanium-8% Manganese Alloy). G. A. LENNING, C. M. CRAIGHEAD AND R. I. JAFFEE. *Trans. Am. Soc. Metals*, 48, 726-733; disc., 733-741 (1956).

Hydrogen pickup during sodium hydride descaling of titanium and titanium alloys was found to be increased by large surface area/mass ratio, presence of β phase in the alloy and time of treatment. Hydrogen absorption decreased with increasing temperature up to 425°C, above which it increased once again; metal removal, on the other hand, increased progressively with temperature. No hydrogen contam-

ination was found using Virgo descaling bath. Acid pickling gives little contamination in α -alloys, but is appreciable in α - β alloys particularly with scale-free surfaces.—BNF. 13628

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.5

The Corrosion Resistance of Steel IKh18N9T. (In Russian.) E. I. ASTROV. *Metallovedenie i Obrabotka Metallov*, No. 1, 30-34 (1957) Jan.

Studies of corrosion resistance of stainless steel of the composition: carbon, manganese, silicon, chromium, nickel and titanium. Intercrystalline corrosion failure is determined chiefly by the ratio of titanium carbide; as the value of this ratio goes up, corrosion goes down.—BTR. 13766

6.2.5, 3.5.8

Avoidance of Stress Corrosion in Austenitic Steel Equipment. C. EDELEANU. *Corrosion Technology*, 4, No. 2, 49-52 (1957) Feb.

Summarizes present knowledge on subject and discusses stress corrosion in plant using chloride or caustic solutions and plant using water or steam. Concentrated chloride or caustic solution and high temperature are conditions necessary for stress corrosion to occur. Little or nothing can be done by heat treatment. All austenitic steels are susceptible in different degrees. Improvement by increasing nickel content is not sufficient to justify use of higher-nickel steels solely on stress-corrosion considerations. Examples under consideration include refrigeration plant using calcium chloride brine and sterilized with steam, evaporator, hot water tanks and presence of steam pockets and concentration effects in laboratory stress-corrosion apparatus.—INCO. 13773

6.2.5, 3.8.4

Electron Diffraction Examination of Surface Layers of Stainless Steel Attacked by Ammonia Gas at High Temperature. T. NAKAYAMA. Paper before Japan Inst. Metals, Spring Mtg., April, 1956. *J. Japan Inst. Metals*, 20, No. 5, 288-291 (1956) May; *Library Abs. Bull. Tokyo*, No. 2, V-2 (1956) Jan.-June.

Surface layers were studied of 13 chromium, 25 chromium, 18-8 and 7 molybdenum stainless steels attacked by an atmosphere containing ammonia gas and a small amount of air at 700°C to explain the relation between the corrosion-resisting nature and the behavior of chromium, nickel and molybdenum. Iron nitrides (mainly Fe_3N) and spinel type oxides are formed on the corroded surface of 13 chromium and high molybdenum steels and chromic nitride crystals are produced inside these surface layers. Corroded surfaces of 18-8 and 25 chromium steels are covered by protective spinel type oxide films. In 18-8, nickel layers (or γ phase layers) are considered not only to retard the diffusion of iron, chromium and nickel from the interior to the surface, but also to prevent the penetration of ammonia gas towards the interior.—INCO. 12747

6.2.5, 3.7.3

Time-Temperature Dependence of Austenitic Stainless-Steel Welded Joint Components. J. HEUSCHKE. Paper be-

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fore Jt. Mtg. Am. Soc. Mech. Engrs. Metals Eng. Div. Conf. and Am. Welding Soc. Nat'l Spr. Mtg., Buffalo, May 7-11, 1956. *Welding J.*, 35, No. 12, 569s-581s (1956) Dec.

Enumerates and illustrates several phenomena which account for differences in short-time and long-time mechanical properties of as-furnished base metal, of welding heat- and strain-affected zones of base metal and of as-deposited weld metal at any one temperature. Equivalence between weldability, ductility, composition, microstructure and its orientation for 300 series weld components is shown. Weldability ideal is defined as freedom from cracks of macroscopic size for designed life of structure under temperature-stress-environmental conditions involved. Sigma phase formation is discussed. Cracking due to heat treatment is discussed for castings, weld metal, forgings, sheets, plates and composite weld-base metal. Short-time tensile and stress-rupture properties for weld metal are summarized. Best short-time weld-metal hot ductility secured was with Type 307. By converting time-temperature relations of weld cooling cycle to temperature-stress relations, for both weld and base metals, safest conditions for any joint may be determined. Numerous tables, graphs, photomicrographs.—INCO. 13603

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.3

Interaction of Chromium (VI) Anions with Chromium Metal Surfaces. SHERMAN KOTTE AND L. O. MORGAN. *J. Phys. Chem.*, 60, 738-741 (1956) June.

Electrode potential changes are correlated with adsorption of chromium anions on a chromium metal surface. Three classes of chromium metal surfaces were recognized. Graphs. 14 references.—BTR. 12764

6.3.4

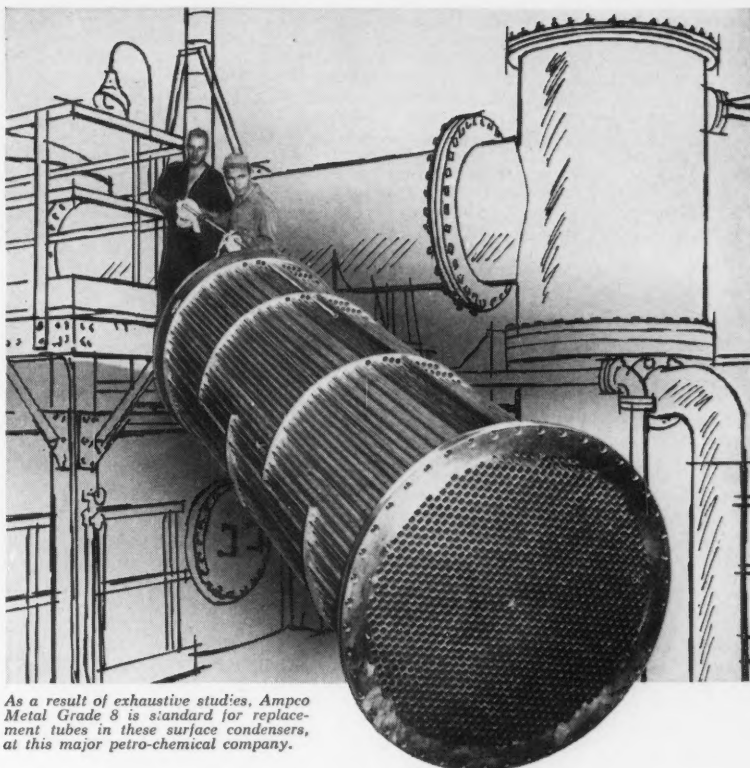
Creep, Rupture and Notch Sensitivity Properties of S-816 Alloy up to 1650 F Under Fatigue and Static Stress. F. VITOVEC AND B. J. LAZAN. Paper before Am. Soc. Testing Materials, 58th Ann. Mtg., Symp. on Metallic Materials for Service Above 1600 F, Atlantic City, June 30, 1955. ASTM Special Technical Publication No. 174, 1956, 69-88; disc., 89.

Fatigue, rupture and creep data obtained under various combinations of mean and alternating stress are presented for S-816 alloy at 75, 1350, 1500 and 1600 F. Specimens were unnotched and notched with stress concentration factors of 2.4 and 3.4. Data are presented as S-N curves and stress range diagrams to show effect of notch, temperature, ratio of alternating-to-mean stress and stress magnitude on fatigue and creep properties. Specimen preparation, testing equipment and procedure are discussed. Role of creep and fatigue as design factors and relation of notch sensitivity to loading conditions are considered. Graph.—INCO. 12772

6.3.4, 3.7.2

Investigation of Forged Cobalt Base Alloys for High Temperature Applications. (Period Covered February 1, 1955 to May 31, 1956). R. R. MACFARLANE, R. K. PITLER AND E. E. REYNOLDS. Allegheny Ludlum Steel Corp. U. S. Atomic Energy Comm. Pubn., Tech. Rept. 56-327, August 1, 1956, 35 pp.

Developmental studies were made of



As a result of exhaustive studies, Ampco Metal Grade 8 is standard for replacement tubes in these surface condensers, at this major petro-chemical company.

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On-job tests prove deterioration rate for Ampco Metal tubing one-third lower than for copper

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In one 34-day test, specimens were placed at the entrance to the tubes. Results showed that Ampco Metal Grade 8 would give about 50% longer service than the original copper tubes.

A later 45-day test — with samples placed away from tube sheets to minimize erosion — showed Ampco Metal Grade 8 superior to other copper-base and stainless alloys.

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...in 45-day corrosion test:

Ampco Metal Grade 8	0.0046
Aluminum brass	0.009
Silicon bronze	0.018
Type 316 (high Mo)	0.020
Hastelloy B	0.0038
Allegany	0.008
Nional	0.0019

In both tests ...

Temperature was 200° — 270°
Acid concentration was 0-5% H_2SO_4
Data from Chemical Engineering, Feb., 1957

PI-3

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a wrought cobalt-base alloy for applications at high temperatures. Additions of aluminum improved oxidation resistance and lowered rupture strength. Boron additions up to 0.2% increased rupture strength and ductility. This increase was limited by a necessarily low solution temperature of 2150 F since, at 2200 F, eutectic melting of a boron phase occurred. Titanium additions resulted in a large increase in room temperature hardness through an ageing reaction but yielded no improvement otherwise. Attempts at improving the workability of unforgeable air melted modifications by vacuum consumable electrode and vacuum induction melting techniques were not successful. (auth).—NSA. 13637

6.3.4, 3.7.3, 8.9.1

Engine Performance of Overtemperature Heat-Treated S-816 Buckets. R. A. SIGNORELLI, F. B. GARRETT AND J. W. WEETON. Lewis Flight Propulsion Lab. National Advisory Cttee. for Aeronautics, Research Memo E55LO6a, March 2, 1956, 26 pp.

Effect of short-time overtemperature heat treatments between 1500-2350 F on turbojet engine performance of S-816 buckets. Overtemperature heat-treated and standard Air Force stock buckets were run in a J33-9 turbojet engine for cycles comprising 15 minutes at rated speed and 5 minutes at idle speed. Results indicated that none of the overtemperature heat treatments adversely affected bucket life. Differences in the as-overtemperated microstructure and in bucket creep rate suggested that stress rupture strength was changed by overtemperature heat treatment. Bucket life was not reduced, because factors other than stress rupture influenced failure. Graphs, photomicrographs, tables.—INCO. 13661

6.3.5

Niobium. F. G. Cox. *Welding and Metal Fabrication*, 24, No. 10, 352-358 (1956) Oct.

Physical and mechanical properties; corrosion resistance in aqueous media

and to molten sodium-potassium (possible selection for canning material in reactors); general working characteristics (unusual features arising from high melting point 2500 C); machining and tooling, recommendations; welding (argon-arc, resistance), micrographs of typical welds.—BNF. 13550

6.3.6, 3.2.2

Intercrystalline Brittleness of Beta (Containing Aluminium.) A. R. BAILEY. *Metal Ind.*, 89, No. 22, 449-452 (1956) Nov. 30.

Summarizes (with further microscopic evidence) recent results which suggest that in these materials grain boundary segregation of aluminum or zinc has taken place.—BNF. 13496

6.3.6, 3.5.9, 3.2.2

Effect of High and Low Temperatures on the Notched-Bar Characteristics of a Cast High-Tensile Beta-Brass. A. R. BAILEY, R. MACDONALD AND L. E. SAMUELS. *J. Inst. Metals*, 85, No. 1, 25-29 (1956) Sept.

Impact tests (—195 C to +800 C) on a commercial brass (61.24 copper, 29.93 zinc, 5.04 aluminum, 1.34 iron, 2.07 manganese, 0.15 nickel). There is a brittle range with intercrystalline fractures at 200-650 C, after which the alloy becomes plastic. Microstructure consisted of β grains with iron-bearing constituent dispersed within them and apparently in smaller form at the boundaries; it dissolved gradually above 550 C. No evidence that intergranular constituent was the cause of the intercrystalline weakness.—BNF. 13487

6.3.6, 3.5.9, 1.6

Elevated-Temperature Properties of Coppers and Copper-Base Alloys. ASTM Special Technical Publication No. 181, April, 1956, 248 pp. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pennsylvania.

Another of a current series of reports prepared under the auspices of the Data and Publications Panel of the ASTM-ASME Joint Committee on the Effect

of Temperature on the Properties of Metals. This report is primarily a graphical summary of the available data including modulus of elasticity, tensile strength, yield strength (0.5% extension and 0.2% offset), reduction of area, elongation, stress for creep rates of 0.000001, 0.00001 and 0.0001% per hour and stresses for rupture in 100, 1000, 10,000 and 100,000 hr.—EL. 13488

6.3.6, 3.7.2

Effects of Titanium on the Properties of Binary Copper Alloys. R. KAWACHI. *Sumitomo Metals*, 8, No. 4, 29-35 (1956) October.

Effects of titanium (up to 3%) on copper-binary alloys including copper-nickel. Hardness of ingot specimens annealed, quenched and tempered condition, micro-grain size and corrosion resistivity against 10% sodium hydroxide, 5% hydrochloric acid, 5% sulfuric acid and 6% sodium chloride + 0.3% hydrogen peroxide were tested. Titanium refines structure and increases hardness of ingot. Hardening effect decreases with increase of amount of third element. Hardness of any rolled or annealed sheet is increased as grain is refined and grain growth is inhibited. Large temper-hardening of binary copper-titanium alloy decreases with increasing amount of any third element. Effects of titanium on corrosion resistance are not marked. Photomicrographs, tables, graphs.—INCO. 13609

6.3.6, 3.7.3

The Inert-Gas Shielded-Arc Welding of Copper and Its Alloys. LOTHAR WOLFF AND WILHELM MANTEL. *Z. Metallkunde*, 47, No. 7, 459-465 (1956).

Inert-gas shielded-arc welding has successfully overcome the major difficulties encountered in welding thick sections of copper and copper-base alloys. The alloys themselves can be divided into two classes, viz. those which are easy to weld, e.g. tin-, silicon-, beryllium- and aluminum-containing bronzes, and those—brasses and special brasses—which are difficult to weld owing to volatilization of zinc. The following aspects of the successful welding, by the Argonarc and the Sigma processes, of both types of materials are discussed: (1) Equipment—for both hand and automatic techniques: argon gas cylinders, electrical equipment, control mechanisms, welding torches, electrodes; (2) Filler rods, and their composition—which depends partly upon that of the parent metal and partly on whether strength, ductility, or corrosion-resistance is the prime requirement of the finished weld; (3) Correct joint design—preparing edges and setting up the work, suitable jigs, clamps, etc.; (4) Operating data—preheating, electrode diameter, current range, filter wire, argon flow, welding-arc speeds; (5) Economics; and (6) Analysis, properties and mechanical strength of the welds. Much of the data are tabulated.—MA. 13713

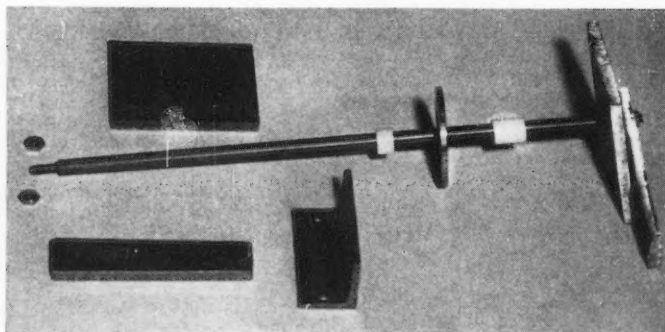
6.3.6, 7.7, 3.4.6, 3.5.8

Atmosphere Affects the Stress-Corrosion Failure of High Brass: A Technical Note. C. H. HANNON. *Corrosion*, 13, No. 6, 417-418t (1957) June.

Observed failures of high brass parts after prolonged service as arcing gap electrodes in electrical apparatus led to a special laboratory investigation. Failure of the electrodes was evidenced by disintegration, embrittlement, cracking and obvious oxidation. This article re-

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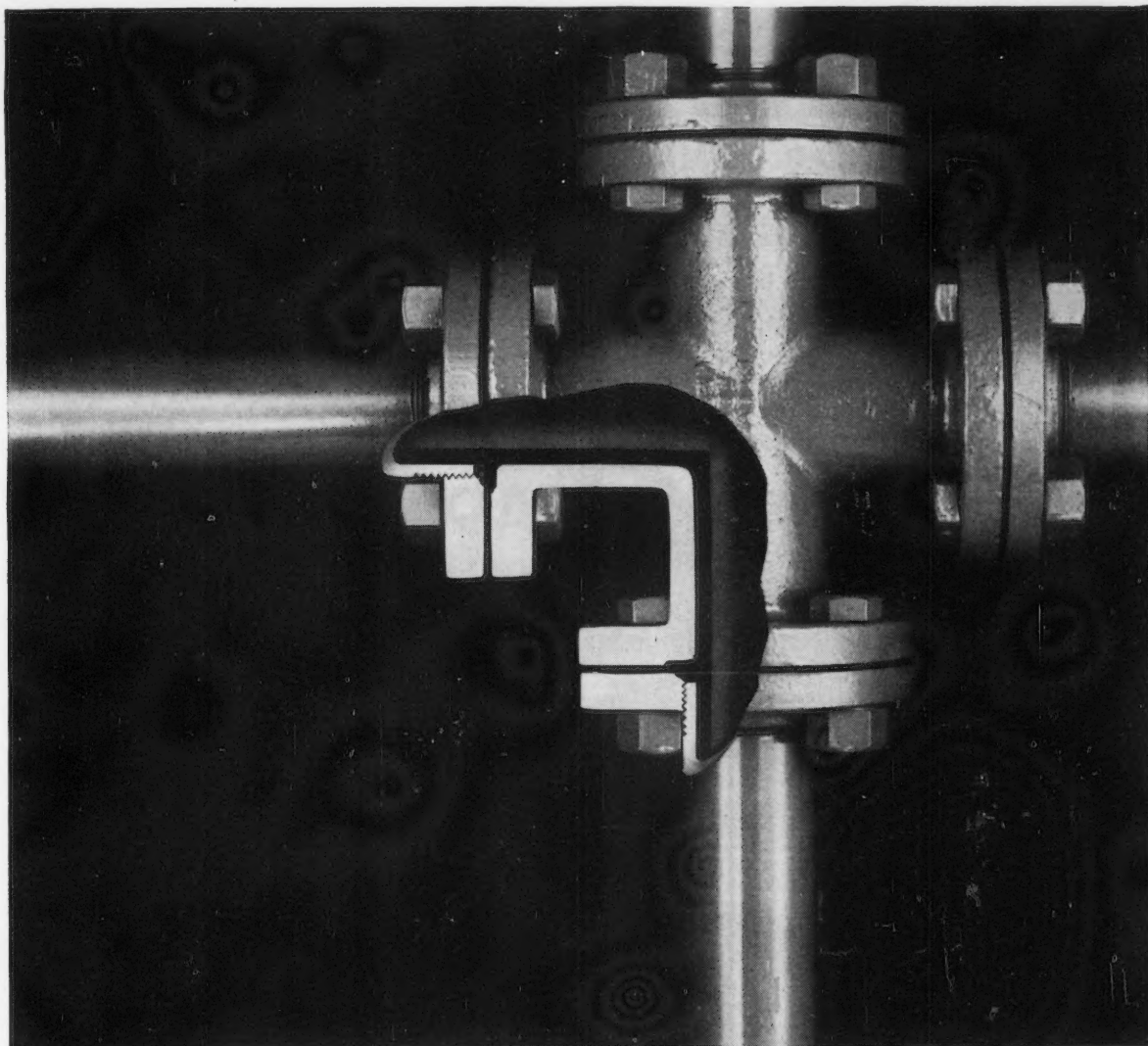


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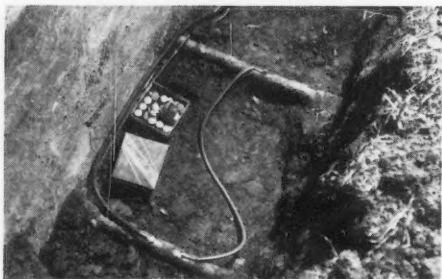
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ports the observations made covering the effects of ammonia, oxygen, nitrous oxide and ozone on highly stressed brass test pieces. 13710

6.3.17, 2.1.1, 4.3.5, 3.7.2

Statistical Analysis of the Corrosion of Uranium. Part I. Tests in Moist Helium and the Effects of Impurities. JAMES T. WABER, Los Alamos Scientific Lab. U. S. Atomic Energy Comm. Pubn., LA-1355, January 31, 1952 (Declassified May 22, 1956), 23 pp. Available from Office of Technical Services Washington, D. C.

Rate data concerning the corrosion of uranium have been treated statistically. A partial analysis of the effect of impurities has been made. The methods and equations are briefly explained. Rate constants and time dependences of the corrosion reaction, represented by a general equation $w = kt^m$ have been obtained. The data were plotted on log-log paper and the line of regression used. Only data for exposure to moist helium have been dealt with in this report. (auth).—NSA. 13702

6.3.19

Study of Corrosion of Alloys of the System Zinc-Antimony. (In Russian.) I. M. BOKHOVIN. *J. Applied Chem., USSR* (Zhur. Priklad. Khim.), 29, No. 8, 1298-1299 (1956).

A letter.

13518

6.3.20, 3.7.2

Constitution Diagram of the Antimony-Zirconium Alloy System. R. F. RUSSI, JR. AND H. A. WILHELM. Ames Lab. U. S. Atomic Energy Comm. Pubn., ISC-204 (deleted version AECD-3610), August, 1951 (Declassified June 5, 1956), 49 pp.

Antimony-zirconium alloys were prepared by diluting a master alloy of 23.6 wt.% antimony with magnesium-free sponge zirconium. The master alloy was made by diffusing analytical grade antimony into sponge zirconium in a sealed stainless steel container at a temperature of about 825 C. These alloys were studied by microscopic examination of slow-cooled and quenched specimens. Thermal analysis and fusion temperatures as well as X-ray, corrosion and hardness data were obtained. The addition of antimony to zirconium was found to bring about a peritectoid transformation, raising the solid α -to- β transformation for Bureau of Mines sponge zirconium from about 925 C to approximately 980 C. The beta zirconium solid solution extends to 14 wt.% antimony at the eutectic temperature of 1430 C and this drops off to about 2% at the peritectoid temperature. Antimony is soluble to about 2.5 wt.% antimony in alpha zirconium from room temperature to the solid transformation. A eutectic was located at about 22% antimony. A compound which is reactive with water and atmospheric moisture was identified at Zr_3Sb . Antimony was found to harden zirconium in all cases, making increasingly brittle alloys as the compound was approached. The resistance to corrosion by 315 C water was increased by certain additions of antimony. (auth)—NSA. 13667

6.3.20, 4.6.1

The Corrosion Behavior of Some Zirconium 8 w% Uranium Alloys in 680 F



zirconium will find
an important place
as a chemical plant
construction material

Cost vs. performance is the measuring stick, of course, by which construction materials are judged. In the recent past, zirconium has been very costly, and it was not generally available industrially. Its performance was in the process of exploration and evaluation. Consequently, its use was limited to applications where its unique properties were essential.

Today we can foresee the fabrication of zirconium parts at only 10 to 100 per cent higher cost than producing equivalent parts of stainless steel. Nevertheless, it is probably still too costly to produce here and where zirconium metal is more readily available. A few predictions can be made, though, from the facts we now have.

Both acids and alkalis are resisted by zirconium. There is one class of acids—sulfuric acid—that requires special attention. It is not resistant to concentrated sulfuric acid at room temperature. An example is found in the equipment that must handle acid and alkali solutions yet maintain a positive pressure. Zirconium resists concentrated sulfuric acid, even when the acid is at room temperature. Zirconium resists concentrated sulfuric acid, even when the acid is at room temperature. Zirconium resists concentrated sulfuric acid, even when the acid is at room temperature.

How composition affects corrosion resistance

Corrosion of any metal is a highly complex phenomenon and any general data should be viewed with caution. In practice, to ensure resistance to corrosion, a few rules must be followed. With this caution, a few remarks about the relationship between composition and corrosion may be helpful. High-temperature water is the medium in which most data are available. Therefore, these general rules are in terms of hot water and steam.

Zirconium as an impurity in stainless steel has a decidedly harmful effect on its

Attack by alkaline solutions is resisted successfully. Furthermore, zirconium has excellent resistance to such violently corrosive materials as fused alkalis.

Many equipment applications for zirconium are expected where previously used materials are considered in both the resistance to corrosion and the mechanical properties. Chemical engineers, plastic engineers and similar materials perform well with zirconium and similar materials.

But it would be highly desirable to use a metal for these and other components. Heat transfer elements, valves, mixing devices, transfer elements, and other specialized parts. The use of zirconium metal is not limited to the advantages of metal used but is limited to the advantages of metal used.

Corrosion, a few structural metal, widens the range of possibilities for the chemical plant designer. It offers him more places where to place his equipment and materials. It will let him cut plant down time. It will also save him money through longer equipment life.

How rapidly zirconium is adopted in equipment design depends principally on the equipment designer's familiarity with zirconium and its properties and relative cost to other materials at hand.

other than to a lower extent. Harmful elements which may be present as impurities, such as copper, aluminum, silicon, magnesium, chlorine, silver and lead, all reduce zirconium's resistance to corrosion.

Alloys containing zirconium with tin or even greater amounts of tin are more resistant to corrosion. Alloying zirconium with tin or even greater amounts of tin are more resistant to corrosion.

A few alloys of zirconium have been developed. One, termed Zircaloy 2, is an alloy containing 1.5% tin, 0.1% niobium, 0.05% copper, 0.05% iron, and a maximum of 40 ppm vanadium. Another, termed Zircaloy 4, contains 0.25% tin, 0.1% niobium, 0.05% copper, 0.05% iron, and a maximum of 40 ppm vanadium. These alloys have the virtue of making the effects of corrosion less severe. Their corrosion resistance is essentially as good as that of high-purity zirconium under most conditions, and they offer the extra advantage of greater strength.

alloys have the virtue of making the effects of corrosion less severe. Their corrosion resistance is essentially as good as that of high-purity zirconium under most conditions, and they offer the extra advantage of greater strength.

Corrosion Properties of Zirconium and Other Metals

The following table shows corrosion resistance, in percent, to various acids, alkalis, and organic liquids, at room temperature, in degrees F., and resistance to corrosion, in percent, to various acids, alkalis, and organic liquids, at room temperature, in degrees F., and resistance to corrosion, in percent, to various acids, alkalis, and organic liquids, at room temperature, in degrees F.

Material	Concentration	Temperature	Corrosion Rate	Notes
Aluminum	10% H ₂ SO ₄	100° F.	100%	
Aluminum	10% HNO ₃	100° F.	100%	
Aluminum	10% HCl	100° F.	100%	
Aluminum	10% HF	100° F.	100%	
Aluminum	10% NaOH	100° F.	100%	
Aluminum	10% KOH	100° F.	100%	
Aluminum	10% NH ₄ OH	100° F.	100%	
Aluminum	10% CH ₃ COOH	100° F.	100%	
Aluminum	10% H ₂ O ₂	100° F.	100%	
Aluminum	10% H ₂ O	100° F.	100%	
Aluminum	10% Air	100° F.	100%	
Aluminum	10% SO ₂	100° F.	100%	
Aluminum	10% CO ₂	100° F.	100%	
Aluminum	10% H ₂ S	100° F.	100%	
Aluminum	10% NH ₃	100° F.	100%	
Aluminum	10% CH ₄	100° F.	100%	
Aluminum	10% C ₂ H ₆	100° F.	100%	
Aluminum	10% C ₃ H ₈	100° F.	100%	
Aluminum	10% C ₄ H ₁₀	100° F.	100%	
Aluminum	10% C ₅ H ₁₂	100° F.	100%	
Aluminum	10% C ₆ H ₁₄	100° F.	100%	
Aluminum	10% C ₇ H ₁₆	100° F.	100%	
Aluminum	10% C ₈ H ₁₈	100° F.	100%	
Aluminum	10% C ₉ H ₂₀	100° F.	100%	
Aluminum	10% C ₁₀ H ₂₂	100° F.	100%	
Aluminum	10% C ₁₁ H ₂₄	100° F.	100%	
Aluminum	10% C ₁₂ H ₂₆	100° F.	100%	
Aluminum	10% C ₁₃ H ₂₈	100° F.	100%	
Aluminum	10% C ₁₄ H ₃₀	100° F.	100%	
Aluminum	10% C ₁₅ H ₃₂	100° F.	100%	
Aluminum	10% C ₁₆ H ₃₄	100° F.	100%	
Aluminum	10% C ₁₇ H ₃₆	100° F.	100%	
Aluminum	10% C ₁₈ H ₃₈	100° F.	100%	
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Aluminum	10% C ₂₀ H ₄₂	100° F.	100%	
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Aluminum	10% C ₂₂ H ₄₆	100° F.	100%	
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Aluminum	10% C ₂₄ H ₅₀	100° F.	100%	
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Aluminum	10% C ₂₇ H ₅₆	100° F.	100%	
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Aluminum	10% C ₇₃ H ₁₄₈	100° F.	100%	
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Aluminum	10% C ₉₉ H ₂₀₀	100° F.	100%	
Aluminum	10% C ₁₀₀ H ₂₀₂	100° F.	100%	

Corrosion data from "Corrosion in Practice and Progress" Bulletin 345, Bureau of Mines, U. S. Government Printing Office, 1954.

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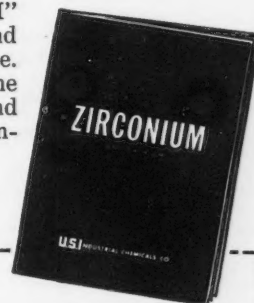
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ties of zirconium compared with other important metals . . . phase diagrams of twenty binary alloy systems . . . descriptions of several fabrication techniques.

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Water. DONALD C. BELOUIN. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-M-DCB-1, Dec. 5, 1956, 12 pp. Available from Office of Technical Services, Washington, D. C.

The corrosion behavior of uranium-zirconium alloys in high temperature water is significantly affected by frequent inspection during long test periods. The effect of heat treatment on these alloys is essentially the same as observed in previous experimental work; namely a quench from 1000 C offers a more favorable structure from a corrosion view-point than a 575 C anneal. It appears that the minor alloying elements used in preparation of these alloys have a very important part in their resistance to corrosion. Unfortunately the data are not sufficiently broad to allow conclusive evaluation of the effect of these alloying elements independent of heat treatment. (auth).—NSA. 13511

6.3.20, 8.4.5

Proposed Program to Provide Design Data for Zirconium for Use in a Zirconium-Graphite-Sodium Reactor System. F. E. BOWMAN. North American Aviation, Inc. U. S. Atomic Energy Comm. Pubn., NAA-SR-Memo-758, August 7, 1953 (Declassified June 6, 1956), 13 pp. Available from Office of Technical Services, Washington, D. C.

A brief resume of the strength and sodium corrosion data that have been found available in the classified literature is given. Tensile properties of zirconium and zirconium alloys at 500 F, comparison of room temperature and 500 F tensile and creep properties of various tin-zirconium alloys, stress rupture of zirconium-aluminum alloys in sodium at 1000 F and a proposed research program are included.—NSA. 13530

6.3.20, 3.5.9

The Oxidation of Zirconium and Zirconium Alloys in Air. H. R. HOGE. Westinghouse Electric Corp. U. S. Atomic Energy Comm. Pubn., WAPD-MDM-11, May 24, 1954 (Changed from Official Use only July 18, 1956), 29 pp. Available from Office of Technical Services, Washington, D. C.

Data are presented to determine the practical limit for heating strip zirconium and its alloys in air. Tests show that the rate of oxidation at higher temperatures increases rapidly and it is not practical to heat zirconium or zirconium alloy strip in air above 1500 F.—NSA. 13642

6.3.20, 3.7.3

Inert-Tungsten-Arc Butt Welding of Zircaloy-2 Tubes. I. W. LINGAFELTER. Hanford Atomic Products Operation. Paper before Am. Welding Soc., Nat'l. Spring Mtg., Philadelphia, April 8-12, 1957. U. S. Atomic Energy Comm. Pubn., HW-43049 (Rev.), August 1, 1956, 23 pp. *Welding J.*, 36, No. 3, 230-235 (1957) March.

From the information presented, it can be concluded that internally ribbed Zircaloy tubes can be successfully inert tungsten-arc butt-welded together to form long lengths of tubing. The welding procedure described in readily adaptable to an automatic operation using standard commercially available inert arc welding equipment. X-ray quality welds with good mechanical, metallurgical and corrosion properties can be

made using the inert tungsten-arc welding procedure described. Butt-welded tubes can be expected to have good corrosion performance at 350 C and adequate room temperature mechanical properties for use with internal tube pressures of 2200 psi or less. (auth).—NSA. 13643

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2

A Study of Heat Transfer Effects on Aluminum Corrosion. Part I. D. R. DE HALAS. Hanford Atomic Products Operation. U. S. Atomic Energy Comm. Pubn., HW-42585 (Rev.), April 19, 1956, 25 pp. Available from Office of Technical Services, Washington, D. C.

A preliminary study has been made of aluminum corrosion rates in water under heat transfer conditions. The corrosion rates observed correspond to those expected at the mean temperature of the corrosion product film on the surface. Data are also given on the apparent thermal conductivity of the corrosion product film and the thickness of the film as a function of corrosion. These data allow calculations to be made which give approximate values for aluminum corrosion rates under heat transfer conditions. (auth).—NSA. 13570

6.4.2

Design and Production of Aluminum Castings. G. W. BIRDSALL. Reynolds Metals Co. *Aero Digest*, 73, No. 5, 13-19 (1956) Nov.

Discussion of aluminum casting alloys includes reference to nickel additions. Description is given of aluminum casting processes, corrosion resistance and properties of aluminum casting alloys. Data to help designers select casting process and aluminum alloy best suited to meet requirements of product are given. Tables.—INCO. 13506

6.4.2

High-Strength Aluminum Alloy V95. I. N. FRIDLYANDER AND YU. I. KUTAYST-EVA. *Informatsiya o Nauchno-Issledovatel'skikh Rabotakh (USSR)*, No. I-5634, 1956, 62 pp. Abstract: *Metals Review*, 30, No. 2, 35 (1957) February.

Extensive review of the Soviet aluminum alloy V-95, mechanical properties of the aluminum-magnesium-zinc-copper system, the solution treatment, precipitation hardening and corrosion resistance of aluminum-magnesium-zinc-copper system alloys and the effect of manganese and chromium and iron and silicon on the V-95 alloy are presented.—ALL. 13595

6.4.2, 3.7.3

Welding of Large Aluminum Structures. L. ADAMS. Pittsburgh-Des Moines Steel Co. *Civil Eng.*, 26, No. 10, 48-53 (1956) October.

Storage tanks, pressure vessels and process equipment make up the large bulk of the tonnage used in large welded aluminum products, with corrosion resistance and toughness at low temperatures the most important criteria for selection, coupled with recent developments in cutting and welding processes. Tables give specifications of available wrought aluminum alloys. Design, relative economy and welding procedures of

large aluminum structures are discussed. Test results of butt-welded aluminum plate specimens are shown. Photos.—INCO. 13478

6.4.2, 4.2.1

Aluminum Finishes for Exterior Use. J. C. BAILEY AND W. EVANS. *Metallurgia* 53, No. 316, 57-62 (1956).

Aluminum and its alloys are being increasingly subjected to outdoor exposure and require protective and decorative finishes. Recent advances in finishing methods are reviewed in detail, with a full discussion of current techniques and results. Anodizing, including the production of thick anodic films, brightening, chemical finishing, electroplating, painting and vitreous enamelling are considered. 9 references.—MA. 13490

6.4.4, 3.7.2

The Corrosion Resistance of Binary Magnesium-Lithium Alloys in Sheet Form. H. G. COLE. Gt. Brit. Royal Aircraft Establishment, Tech. Note Met-235, Feb., 1956, 8 pp.

Corrosion tests by total immersion in 3% sodium chloride solution and by intermittent sea water spray have been made on sheets rolled from a series of binary magnesium-lithium alloys low in sodium. Alloys containing up to 10% lithium by weight had a corrosion resistance approximately equal to that of magnesium-1.5% manganese alloy sheet and were equally well protected by conventional protective treatments. At lithium contents of 12% and over, corrosion resistance fell rapidly. (auth).—NSA. 13554

6.6 Non-Metallic Materials

6.6.6, 6.7.2, 3.2.3

Regularities and Mechanisms of Oxidation of Hard, High Melting Point Titanium Compounds. (In Russian.) G. V. SAMSONOV AND N. K. GOLUBEVA. Kalinin Moscow Inst. of Nonferrous Metals and Gold. *J. Phys. Chem., USSR (Zhur. Fiz. Khim.)*, 30, 1258-1266 (1956) June.

Oxidation isotherms of dense compact samples of titanium carbide and titanium nitride were found to consist of two regions, the initial curved one and the subsequent linear domain while the titanium boride follows the hyperbolic law. Studies were made by chemical, x-ray and electron diffraction methods of oxide films and their structure and electrical resistance. During the initial period of oxidation (the curved part of isotherm) a dense film of TiC-TiO or TiN-TiO is formed on titanium carbides and nitrides which is followed, in the second period, by the formation of less compact layers of higher oxides of titanium. The oxidation of titanium boride occurs at the expense of the oxygen diffusion through the layer of borates formed on the surface. (tr-auth).—NSA. 13663

6.7 Duplex Materials

6.7.2

A Preliminary Study of Three Cermet Based on Uranium Oxide. L. S. WILLIAMS, D. T. LIVEY, E. BARNES AND P. MURRAY. Gt. Brit. Atomic Energy Research Establishment, Harwell, Berks, England, Rept. M/R-1934, May 4, 30 pp.

The fabrication and some properties

of three cermets were investigated in outline. Fabrication by hot pressing methods is feasible provided an argon atmosphere is used. The thermal shock properties of uranium dioxide are not improved by the addition of zirconium; however the uranium dioxide-thorium system, at high metal contents and to a lesser extent the uranium dioxide-silicon system up to 60 vol.% of metal show improvement in this respect. The poor properties of the zirconium cermets is probably due to oxygen embrittlement of the zirconium as a result of reaction with the oxide constituent. The use of silicon as the metallic constituent at 20% by volume improves the oxidation resistance of uranium dioxide in air at temperatures up to 900 C. Addition of silicon beyond 20 vol.% has little effect on the rate of oxidation. (auth.)—NSA. 13715

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1

Cage Design is Critical for High Speed Ball Bearings. H. HANAU. Gen. Motors Corp. *Aviation Age*, 27, No. 2, 52-57 (1957) Feb.

Discusses 9 basic design parameters applying to cage design, lubrication and dependence of its selection on bearing size and cage materials. S-Monel treated with nickel oxide appears to be best material for operation above 400 F. It has constant coefficient of friction at room and higher temperatures and necessary high temperature strength. Nickel oxide coating cuts galling during run-in. Use of bronze-clad SAE 1010 steel,

phosphorus-bronze, phenolic iron-silicon-bronze and silver-plating is considered. Outer ring riding cages are favored for high speeds of 500,000 DN-1,000,000 DN while one-piece designs are used for ultra-high speeds of over 1,000,000 DN.—INCO. 13739

7.1, 3.5.8

Relation of Engine Turbine-Blade Life to Stress-Rupture Properties of the Alloys Stellite 21, Hastelloy B, Cast S-816, Forged S-816, X-40, Nimonic 80, Refractaloy 26, N-155, and Inconel X. F. B. GARRETT AND C. YAKER. U. S. Natl. Advisory Cttee for Aeronautics, Research Memo E51G13, 1951 (Declassified 1956), 59 pp.

Blade lives of the relatively low-strength alloys (Hastelloy B, N-155, Inconel X, forged S-816, Stellite 21 and Nimonic 80) are predictable on the

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basis of the stress-rupture test values, whereas the lives of the stronger alloys (cast S-816, X-40 and Refractaloy 26) are lower than the levels predicted. In the case of cast alloys, this discrepancy is attributed to vibratory stresses; for Refractaloy 26 the lower life is explained by the fact that corrosion is accelerated by vibratory and thermal stresses. Results of metallographic examinations are given.—MA. 13599

7.1, 4.4.7

A Further Investigation of Disturbances Due to Oil Films in Journal Bearings. J. F. LEWIS AND G. B. FULTON. Rensselaer Polytechnic Institute. U. S. Wright Air Development Center Publ., May, 1956, 29 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C. (Order PB 121519).

Instability characteristics are described for two flexible rotors with critical speeds of about 1300 rpm running in six journal bearings. The whirl impending speeds, with a few exceptions, were near twice critical. A slight decrease in whirl impending speed was noticed with decreasing viscosity. No stable range was observed above the speed at which whirl set in. The ratio of the maximum stable speed to the critical speed is plotted as a function of inlet oil viscosity. A photographic method for determining the running position of a journal bearing is described, along with several determinations of running speed position. Some interesting trends of whirl impending speed with L/D ratio, clearance and temperature are presented. 13649

7.2 Valves, Pipes and Meters

7.2

Lubricated Plug Valves. P. MANOR. *Can. Chem. Processing*, 40, No. 10, 61-62, 64 (1956) October.

Construction, selection of valve for chemical process systems and maintenance and repair are discussed. In stripping plants, where ethane, propane and higher hydrocarbons are removed from natural gas refrigeration nickel steels meet requirements to -150 F, or to -100 F where shock is a factor. Beyond these points, stainless steel lubricated plugs are required. Diagram.—INCO. 13627

7.3 Pumps, Compressors, Propellers, Impellers

7.3, 4.7

AC and DC Conduction Pumps for Liquid Metals. L. R. BLAKE. *Engineer*, 202, 541-544, 572-576 (1956) October 19, October 26.

Chief design features of the various types of conduction pump and behavior at high output powers with liquids such as bismuth. Indicates materials of construction, corrosion resistance and fabrication methods.—BNF. 13503

7.3

Guide to the Selection of Pumps for the Chemical and Process Industries. J. O. S. MACDONALD. *British Chemical Eng.*, 1, Nos. 6, 7, 298-305, 361-368 (1956) Oct., Nov.

Types of pump, characteristics, shaft seals, materials of construction and their

special limitations as regards corrosion resistance and mechanical properties, pump selection, range of available pumps (with materials of construction and representative manufacturers).—BNF. 13646

7.4 Heat Exchangers

7.4.1, 5.2.3

The Protection of Heat Exchangers Against Corrosion. L. C. FERRIS. *Brit. Chem. Eng.*, 2, 122-127 (1957) March.

Occurrence of galvanic and impingement corrosion in heat-exchangers: graphitization of cast iron. Discussion of methods of protection, painting, addition of inhibitors to liquid, streamlining of inlet ends of tube to decrease turbulence and cathodic protection with and without applied current is given. Notes on performance of galvanic anodes of graphite and platinum alloys are included.—INCO. 13760

7.4.1, 8.4.5

Nuclear Power Plant Heat Exchangers Are Different. S. BARON. Paper before Heat Exchanger Inst., May, 1956. *Power Eng.*, 60, No. 12, 83-87 (1956) Dec.

Comparison of problems of corrosion, coolants and design of heat exchangers for nuclear plants to those for conventional ones. Discussion of properties of metals for heat exchangers includes aluminum, stainless, nickel, titanium and zirconium. Effect of radioactive corrosion on metals is discussed. Table shows use of Zircaloy and stainless in fuel element cladding of reactors and in steam generator material. Photos.—INCO. 13485

7.6 Unit Process Equipment

7.6.4, 4.6.2

Effect of Certain Variables on Corrosion of Gas-Fired Domestic Water Heaters. R. C. WEAST. Case Institute of Technology. Am. Gas Assoc., Committee on Domestic Gas Research, Project DJ-4-WH, December, 1956, 24 pp.

When a constant volume of water is withdrawn daily from tanks of the same style but of different volume, corrosion rate per unit tank area is greatest in tanks of smallest volume. Temperature at which a water heater operates markedly influences corrosion rate of heater. After 635 days of operation galvanized steel tanks tested at 140 F showed no corrosion when evaluated by number of rust tubercles formed, whereas those operated at 150 F or higher corroded and showed larger numbers of rust tubercles. Water heaters corroded at a faster rate in zeolite-softened water than in unsoftened water. Corrosion rate of galvanized steel tanks by hot water was 10% greater in tanks with copper dip tubes than in tanks with non-metallic dip tubes. Tanks of center flue construction corroded at a faster rate than did offset flue or floater type tanks. Total amount of oxygen consumed by metal corrosion of tanks having 3 ounces of galvanizing metal per square foot was always less than for tanks of similar style having 2 ounces of galvanizing metal per square foot when tanks were operated at corresponding temperatures in water of same composition. Tables, photomicrographs, graphs.—INCO. 13723

7.6.4, 4.6.2

A Corrosion Problem in Large Steam Generating Stations. T. J. FINNEGAN. *Corrosion*, 13, No. 6, 405t-409t (1957) June.

Internal corrosion of boiler tube surfaces is a serious problem in the electric utility industry. Such corrosion usually takes the form of a pinhole leak which at first does not affect the boiler operation or attract the attention of the operator in the control room. The pinhole increases in size until it is large enough to cause the tube to be torn apart.

Heavy deposits of a black oxide frequently are found in a tube at or near the point of failure. Possible explanations for the presence of this oxide are: (1) Iron removed from the piping and equipment in the pre-boiler circuit may be carried back into boiler when the oxygen-free alkaline environment favors its precipitation as black iron oxide (Fe_3O_4), and (2) Some factors may prevent the formation of the protective film which is needed to prevent bare metal from coming in contact with water. Protective measures based on both premises were put into use.

One method of combatting this type of corrosion involves the maintenance of an optimum concentration of "free caustic" in the boiler water. Another method is to clean the boiler periodically with low strength hydrochloric acid. Many boiler operators found it helpful to make the condensate alkaline in order to protect pre-boiler equipment. Cyclohexylamine, morpholine and ammonia were used in this connection. Although favorable results were reported in many cases, there is still some lack of agreement about the effectiveness of such compounds. 13737

7.7 Electrical, Telephone and Radio

7.7

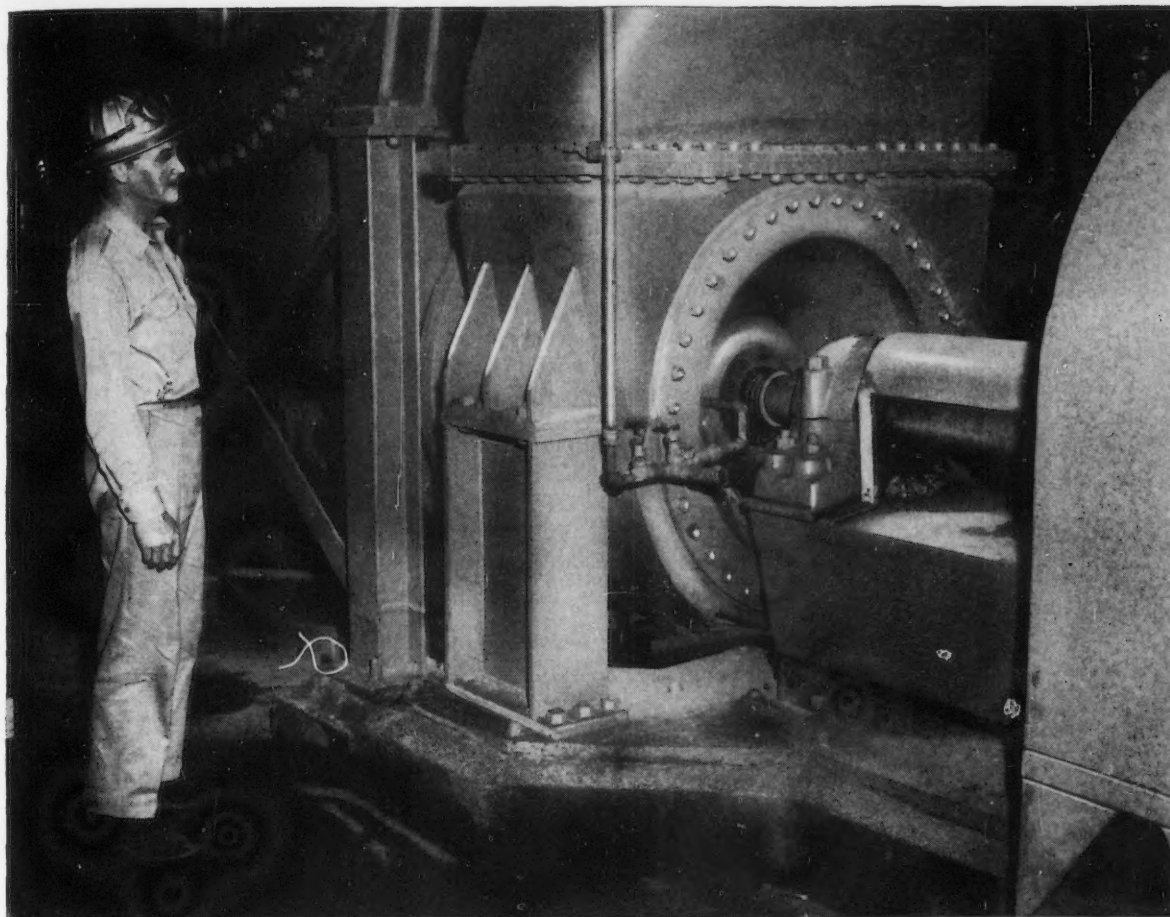
Corrosion Prevention in High Voltage Steel Cables Under Fluid Pressure. (In French.) J. CHANGARNIER AND J. ROLLIN. *Corrosion et Anti-corrosion*, 5, 2-9 (1957) Jan.

A survey of the technical and economical advantages of this type of high voltage cable. Seals must be perfect and short-circuit currents must be grounded during cathodic protection. The special technique and devices used are described.—BTR. 13770

7.7, 4.2.3, 6.3.10

On Brittle Phenomenon of Nickel by Heating in City Gas. S. MIRO. Paper before Japan Inst. Metals, Fall Mtg., October 1954. *J. Japan Inst. Metals*, 20, No. 10, 569-573 (1956) Oct.; *Library Abst. Bull.*, Japan, No. 3, 11-12 (1956) July-December.

Pure nickel is used in vacuum tubes as lead wire. In stem making process or glass sealing process of vacuum tubes the nickel often causes brittleness by heating in a city gas, due to impurity in the nickel. Wires of Inco, Mond, Falconbridge, Driver Harris and domestic nickel were examined. Brittleness was due to the microcracks formed along boundaries by gas attack. When they were heated in a gas purified through the sodium hydroxide and phosphoric anhydride tower and hot copper furnace, brittleness was not observed. An addition of magnesium, silicon, chro-



One of the two cast stainless steel (ACI Type CF-7M) screw pumps used to circulate a highly corrosive salt in a large evaporator at Westvaco Chlor-Alkali Division.

sion, Food Machinery & Chemical Corporation, South Charleston, West Va. The stainless steel castings lasted twice as long as the best material previously used.

Cast stainless steel doubles the life of pump handling hot corrosive salt

The pump above circulates a solution of calcium and magnesium chlorides with 8-10% solid NaCl in suspension. Specific gravity: 1.4. pH value: 6 at 220°F.


Engineers at Westvaco Chlor-Alkali tried a number of materials for this pump.

Copper and bronze parts failed in 15 months. Cast iron parts lasted 3 years. One type of stain-

less steel lasted 4 to 5 years.

They finally found what they wanted in Alloy Casting Institute Type CF-7M (19% Cr, 9% Ni, 2.5% Mo, 0.07% max C) stainless steel castings. These nickel-containing castings have been in service 9 years. *That's twice the life of the best material previously used. And still no sign of corrosion!*

Perhaps a cast (or wrought) stainless steel containing nickel can solve your corrosion problem, or meet some other specific need. For information to help you select the right alloy, get in touch with Inco's Development and Research Division. They'll be glad to help.

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mium, titanium, aluminum and manganese to nickel was useful in preventing brittleness of pure nickel.—INCO. 13689

7.7, 5.3.2

Investigation and Evaluation of Plating Processes and Plated Combinations for Use on Etched Circuitry (Printed Circuits). E. H. BABCOCK, E. K. STEPHENS AND R. C. GRIMSINGER. *Tech. Proc. Am. Electroplaters' Soc.*, 1956, 267-271, 274-275.

Platings in these systems are required to give good connections from front to back in punched holes, abrasion-resistant surfaces for contact strips of plug-in boards, good solderability and corrosion resistance. A series of coatings are tested and rated (bright silver, alone or plus rhodium or plus bright gold; bright nickel, alone or plus rhodium; bright gold; rhodium; matte silver, alone or plus rhodium). A technique for production of reliable etched circuit boards is described.—BNF. 13481

7.8 Wires and Cables—Non-Electrical

7.8, 8.10.3

Corrosion of Mine Cables. J. TEINDL AND E. HILA. *Hutnicke Listy*, 11, 77-86 (1956). Abstract: *J. Applied Chem.*, 6, No. 6, 805 (1956) June.

The general causes of mine cable corrosion, particularly the surface cracking of drawn wire are reviewed. Reference is made to the importance of drawing die condition, the influence of the structure of the material, martensite development, surface protection of wire by polishing and zinc plating and the importance of increasing cable resistance by raising the fatigue limits by preliminary pressure. The need for thorough and effective lubrication of cables in mines is emphasized.—ZDA. 13726

8. INDUSTRIES

8.3 Group 3

8.3.3, 6.4.2

Experience with Aluminum Milk Cans. J. C. BAILEY AND A. W. BRACE. *J. Soc. Dairy Technol.*, 9, No. 4, 155-159 (1956).

The effect of aluminum and aluminum alloys in contact with milk is discussed; copper-bearing aluminum alloys should not be used for milk cans, as small amounts of copper impart a fishy flavor to milk. Results of comparative tests on tinned steel and aluminum cans in Great Britain, Northern Ireland and Canada indicate that aluminum cans are cleaner, less liable to mechanical damage and more resistant to detergents than tinned steel. Large-scale production in a modified design using HS10-WP:B.S. 1470, 14 SWG material and argon-arc welding is in progress in this country. Aluminum strainers have also been tested and proved satisfactory.—MA. 13484

8.3.4

Corrosion and Protection from Corrosion in Brewery Practice. H. BURKLI. *Schweiz. Brauerei-Rundschau*, 67, 18-24 (1956); *J. Sci. Food Agric. Abstr.*, 7, No. 7, ii-29 (1956).

A review, covering types of corrosion, protective coatings of various types, cathodic protection and methods for re-

moving oxygen and carbon dioxide from water.—RPI. 13542

8.3.5

Problems in the Anticorrosive Protection of Materials in the Vegetable Oil Industry. V. MIKASINOVIC. *Zastita Materijala*, 4, No. 9, 295-297, 299 (1956). 13664

8.3.5, 7.5.2

Corrosion Phenomena in Fruit Juice Tins. V. CRNEVIC. *Zastita Materijala*, 4, No. 9, 292-294 (1956).

Factors affecting corrosion and means for its prevention are discussed. 4 references. 13534

8.4 Group 4

8.4.3

Refinery Corrosion Problems. J. TOURRET. *Corrosion et Anti-Corrosion*, 4, 389-399 (1956) Dec.

Study of corrosion of storage tanks for petroleum products; distillation units for crude petroleum; thermal and catalytic cracking plants, refinery units and gas plants (nickel, Monel, stress relief, hydrogen blistering, hydrogen embrittlement).—INCO. 13716

8.4.3, 5.8.2

Selection and Application of Corrosion Inhibitors. J. D. CRAWFORD. *Producers Monthly*, 20, 22, 24-26 (1956) Oct.

Inhibitors in oil industry, corrosive oil wells, determining corrosion rates, protection, pellet type inhibitors, flushing systems.—MR. 13588

8.4.3, 6.2.5

Embrittlement of Twelve Percent Chromium Steel Thermocouple Nozzles on a Thermoform Catalytic Cracking Unit Reactor: Topic of the Month. H. H. BENNETT, Socony Mobile Oil Co., Inc. *Corrosion*, 13, No. 2, 871-881 (1957) Feb.

Several nozzles on reactor fractured during removal of thermocouple wells. Nozzles were of a 11-13 chromium alloy of composition similar to reactor cladding. Metal in nozzle at point of failure had been subjected to 850-1000 F temperatures for 100,000 hours. Photomicrographs show widening of grain boundaries due to precipitates of carbides, sigma phase formation or possibly nitrides and phosphides, which lead to embrittlement.—INCO. 13754

8.4.5

The Application of Materials in Low-Temperature Water- and Organic-Liquid-Cooled Reactors. J. E. DRALEY AND S. GREENBERG. "Symposium on Behavior of Materials in Reactor Environment" (Am. Inst. Mining Met. Engrs.), 1956, 33-53.

Materials used in light water-cooled reactors and their properties are described. Stability under irradiation or thermal cycling and corrosion properties of uranium and thorium, control elements in the form of poison or producer rods or liquids, aluminum- or magnesium-base cladding alloys, structural materials for piping and control systems, the properties and merits of moderating materials, including graphite and beryllium and materials for shielding are included in the description. The problems and advantages associated with the use of light water, heavy water or diphenyl coolants are discussed and compared. 22 references.—MA. 13579

8.4.5

Structural Materials for Use in the Pressurized Water Power Reactor. D. M. WROUGHTON AND D. J. DE PAUL. "Symposium on Behavior of Materials in Reactor Environment," 2956, 55-69: Am. Inst. Mining Met. Engrs., 29 West 39th St., New York 18, New York.

Problems associated with the selection of structural materials for pressurized water reactors are discussed under four headings: (1) corrosion, both general and localized; (2) the release of corrosion products to the water; (3) radiation effects; and (4) wear. Suitable circulating autoclave or pumped loop systems for testing these materials are described. The problems of water technology are discussed and a review is given of the materials which have been selected for reactor use. 7 references.—MA. 13705

8.4.5

Operational Experience with the Borax Power Plant. W. H. ZINN, H. LICHTENBERGER, M. NOVICK, G. K. WHITAM, C. J. B. ZITEK, J. G. FELDES, V. C. HALL, JR. AND R. O. HAROLDSEN. *Argonne Nat. Lab. Nuclear Sci. and Eng.*, 1, No. 5, 420-437 (1956) October.

Brief description is given of Borax-III power reactor and its over-all system. Fuel used is enriched uranium-235 alloyed with aluminum and uranium-aluminum alloy is clad with 2S aluminum. Reactor vessel is stainless steel. Reactor was operated for 1170 hours at 300 psig. Steam generated in reactor was fed directly to turbine. Tests were conducted on maintaining pH and quality of reactor water. Checks were made on carryover of activity into portions of system external to reactor vessel. Water decomposition was measured under various conditions. In attempt to determine corrosion rate variation with varying oxygen concentration in steam, total iron determinations were made of condensate during normal operation and during test period when hydrogen was added to feed water. Water corrosion of the aluminum cladding and possible rupture in the cladding are discussed. In addition to boric acid solution control, each fuel assembly has control burnout strip of 98.4 aluminum-0.6 boron-1.0 nickel. Diagrams.—INCO. 13697

8.4.5

ETR: Design and Construction. P. D. BUSH. *Kaiser Engineers, Nucleonics*, 15, No. 3, 48-56 (1957) March.

Description of ETR atomic energy facility. Materials for system are mainly ferrous. Pressure vessel is of stainless clad carbon steel. Primary coolant piping is of solid 347 stainless and pipes of heat exchangers are 304 stainless. Pumps have carbon steel bodies and austenitic stainless impellers. Intergranular corrosion at welded areas in primary-coolant piping is eliminated by use of 347 stainless. Problem of stress corrosion cracking is minimized by almost complete absence of weld pockets in heat exchangers and piping. Heat-exchanger tubes are made of 304 stainless and shells are of carbon steel. There are 4 internal, concentric, cylindrical thermal shields made of 304 stainless. Diagrams, tables.—INCO. 13763

8.4.5

Selected Abstracts of Atomic Energy Project Unclassified Report Literature in the Field of Radiation Chemistry and Bibliography of the Published Literature.

ture (Papers Noted up to May 1956). Part 6. Miscellaneous (Including Including Industrial Applications of Radiation, Effect of Irradiation on Colloids, Corrosion Effects, Irradiation Requirement, Review Papers, Etc.). R. W. CLARKE, compiler. Gt. Brit. Atomic Energy Research Establishment, C/R-1575 (6), May, 1956, 57 pp.—NSA. 13526

8.4.5

Processing of Power Reactor Fuels. R. E. BLANCO. Oak Ridge Nat. Lab. *Nuclear Sci. & Eng.*, 1, No. 5, 409-419 (1956) October.

Heterogeneous reactor reprocessing problems are discussed from viewpoint of central solvent extraction reprocessing station. Currently proposed fuels are classified according to solvent extraction reprocessing principles; included are fuels containing stainless steel. Described are alternate methods for converting fuels to nitric acid soluble form and effects of radiation and inert alloy metals on solvent extraction method. Stainless steel processing equipment is used in some of the methods. Head-on methods include acid dissolution, oxidation, hydrochlorination, chlorination, carbonization (converts stainless to form from which uranium can be leached with nitric acid), molten metal dissolution and electrolytic dissolution. New processing method, Hermex process, uses mercury as the dissolved agent. Flow-sheets are shown for processing zirconium-tungsten fuels by Zircex process, stainless steel fuels by aqua-regia process and purification of metals by Hermex process.—INCO. 13519

8.4.5, 6.2.5

Corrosion of Stainless Steel Type 309SCb in 200 Area Dissolver Solution Containing Mercuric Ion. KENNETH L. SANBORN. Hanford Works, U. S. Atomic Energy Comm. Pubn., HW-22779, November 20, 1951 (Declassified January 7, 1956), 2 pp. Available from Office of Technical Services, Washington, D. C.

Tests carried out on welded and as-received specimens showed normal corrosion rates except for the welded specimens exposed to control solution. In this case (mercury ion absent), the excessive rate was traced to the presence of inclusions in the weld deposit. The effect of the presence of the mercury ion was therefore considered to be insignificant.—NSA. 13690

8.4.5, 6.2.5, 3.7.3

Effects of Irradiation and Corrosion on Stainless Steel Welded Joints in Pressurized Water Reactors. L. C. GRIMSHAW. Westinghouse Electric Corp. U. S. Atomic Energy Comm. Pubn., WAPD-AD(P)-987, May, 1955 (changed from Official Use Only October 23, 1956), 6 pp. Available from Office of Technical Services, Washington, D. C.

After approximately 2900 hours exposure in the Mark I system at temperature and pressure, a fillet weld between pipe and coupling was found to have suffered no damage from corrosion. No crevice corrosion was observed between pipe and coupling or in the root. There was no cracking at the root. There was present about 2% of ferrite in the weld deposit. Weld, pipe and coupling were type 347 stainless steel. It was observed that despite the fact that the deposited weld metal was out of chemical specification, being too high in carbon and hence low in the amount of

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ferrite in its structure, there was no evidence of cracking, either at the time of making the weld, or during life in service. (auth).—NSA. 13581

8.4.5, 6.3.20, 3.5.8

Fretting Wear of Zircaloy-2 Pellets and Consequences Thereof. LOUIS A. WALDMAN AND PAUL COHEN. Westinghouse Electric Corp. U. S. Atomic Energy Comm. Pubn., WAPD-CPM-3, January 9, 1956, 22 pp. Available from Office of Technical Services, Washington, D. C.

Because results of earlier, short-term tests conducted to determine fretting wear rates in a packed bed of Zircaloy pellets were inconclusive, a new test was designed and conducted in which significant fretting wear rates were traced by using irradiated pellets. The results of this test were combined with observations from the earlier tests and an analysis made of two hazards associated with the operation of a packed bed reactor as consequences of fretting wear: cladding penetration and Zr⁹⁰ activity release. The analysis shows that neither of these hazards is seriously affected by fretting wear. (auth)—NSA. 13735

8.8 Group 8

8.8.1

Corrosion Problems in Chemical Factories. Part I. Choice of Construction Materials. F. R. HIMSWORTH AND J. G. HINES. *Chemical Age*, 77, 285-289 (1957) Feb.

Current practice in corrosion prevention.—MR. 13742

8.8.1., 3.1

Corrosion in the Chemical Industry. (In French.) PIERRE BACHMANN. *Chimia* (Switzerland), 10, No. 8, 189-194 (1956) August.

Different corrosion mechanisms, chemical and electrochemical corrosion, measurement of corrosion.—MR. 13494

8.9 Group 9

8.9.1

A Re-Evaluation of Some Air-Frame Thermal Problems. N. F. DOW. Paper before Inst. Aeronaut. Sci., Los Angeles, June 18-21, 1956. *Aeronaut. Eng. Rev.*, 15, No. 11, 61-66, 85 (1956) Nov.

Second approximation of significance of problems of material selection, thermal stresses and inelasticity or creep encountered in the air frame in supersonic flight. Loss of stiffness, loss of strength and structural inadequacy due to high thermal stresses are discussed. Data are included for 17-7 PH. Graphs.—INCO. 13572

8.9.3

The American Louisiana Pipeline. Part IV. Line Coating. Cathodic Protection. J. F. EBDON. *Gas*, 32, No. 10, 156-157, 160, 163 (1956) Oct.

Description of operation of cleaning and priming machines and coating and wrapping units during construction of pipeline. Plastic enamel primers and glass fiber pipeline felts were used in protective coatings. Cathodic protection was applied after heavy construction work was completed. Tests carried out to prove pipeline are described. Photos.—INCO. 13567

THESE TESTS PROVE CORBAN PREVENTS CORROSION BEST

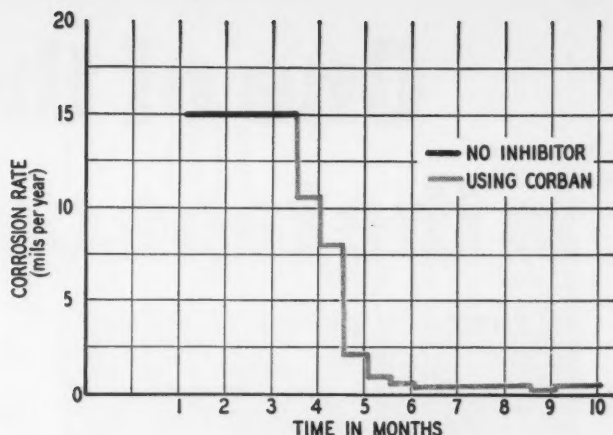
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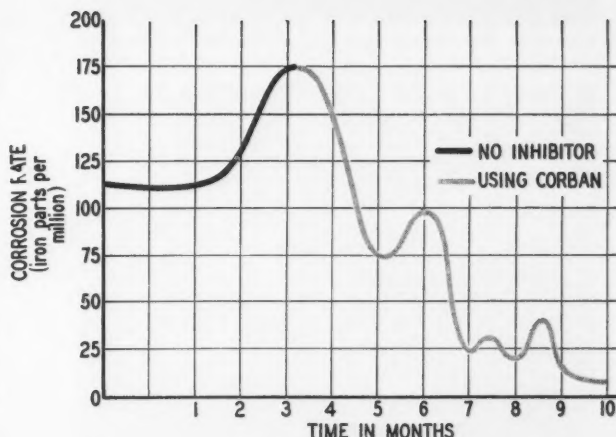
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STANDARD TEST uses metal strips inserted in wellhead or tubing. Surface penetration or weight loss indicates degree of corrosion.



2

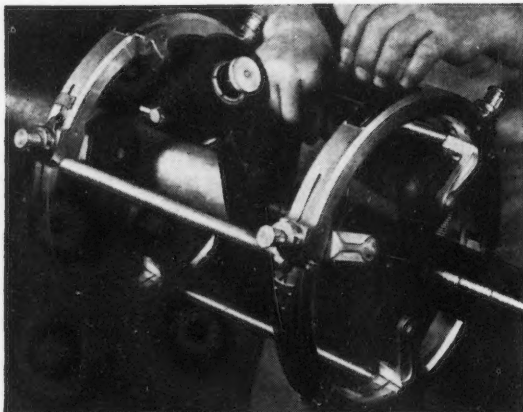
FLUID ANALYSIS is quick test of corrosion in gas condensate wells. Chart shows parts per million of dissolved iron in water sample.

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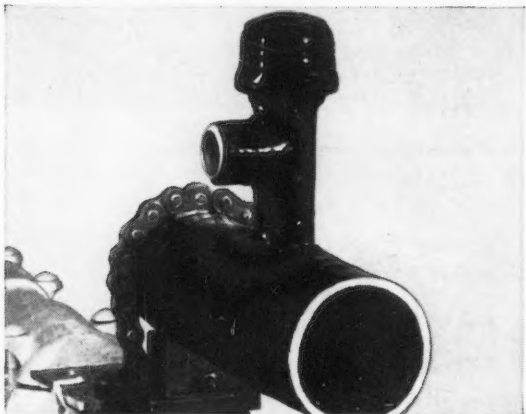
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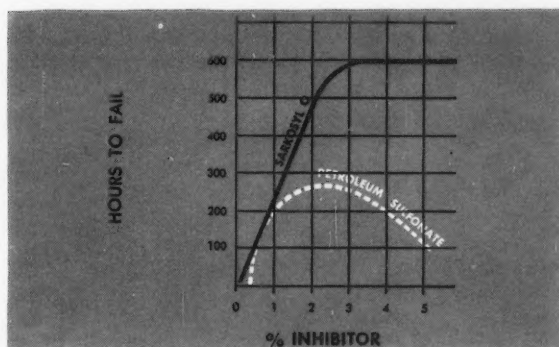


Figure 1.

STATIC WATER DROP TEST: As little as 50 ppm SARKOSYL O in a solvent extracted turbine grade lubricating oil in contact with distilled water prevented rusting for two weeks. As much as 250 ppm of other commercial inhibitors was required to get the same degree of protection. Using seawater as the corrosive medium, 0.05% SARKOSYL O afforded 20 hours protection; other commercial inhibitors tested prevented rusting for as little as 60 minutes in this test. Using a silicone oil, 0.0125% SARKOSYL O prevented rusting for one week in contact with distilled water, was unaffected by 8 hours heating at 450° F.

GASOLINE TANKER TEST: This test simulates conditions in an ocean-going tanker first with bulkheads filled with clean cargo, then ballasted with seawater or empty for the return trip. Rusty, rather than clean test panels are used in this test. These are prepared by immersing in seawater for several days and are then immersed in gasoline containing inhibitor for one week. Half of the panels are then immersed in seawater for another week; the rest are rotated for an equal period in a fine mist of seawater. The results are noted in the following table:

	Percent Protection		
	Concentration	Sea-water Immersion	Sea-water Spray
SARKOSYL O	0.0025%	44%	6%
	0.0200%	71%	37%
INHIBITOR C	0.0025%	13%	0%
	0.0200%	19%	6%

PROPERTIES

SARKOSYL O

$C_{17}H_{33}CON(CH_3)CH_2COOH$

Molecular Weight..... 340-350
Setting Point..... 0°C
Color (FAC)..... 10
Oil Solubility..... miscible
Specific Gravity..... 0.948

Send for literature and samples

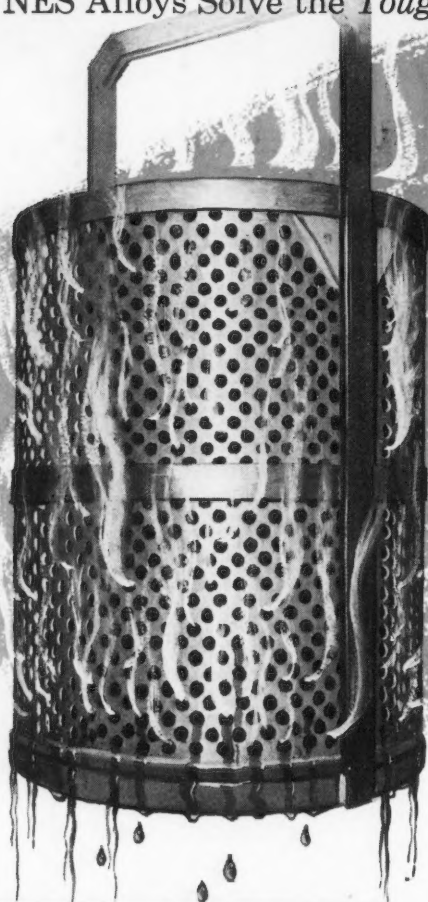


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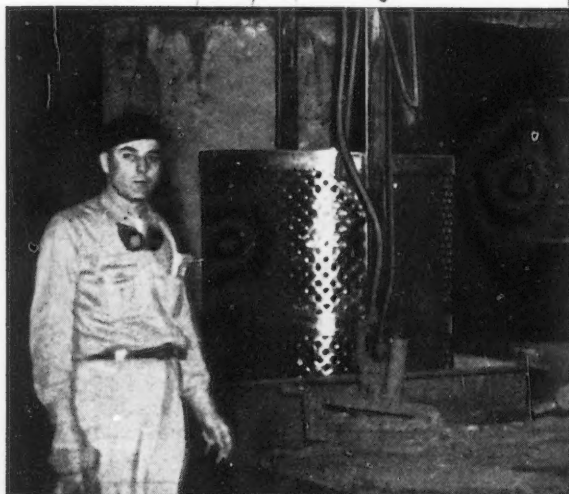
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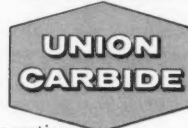
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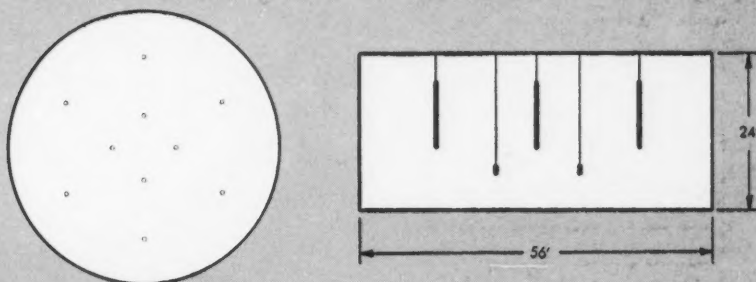
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Diagrammatic drawing showing method of installation and placement of anodes.



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VOLUME 13

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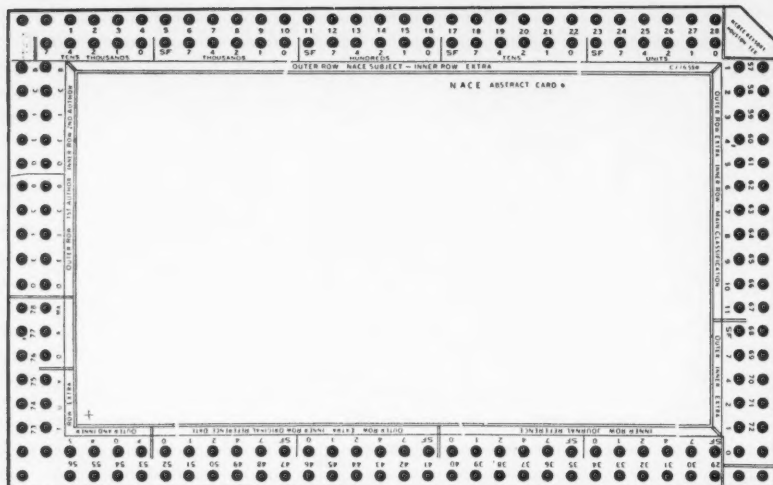
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CORROSION ABSTRACTS

As Published in

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* The following designations apply to the several groups listed under 8. INDUSTRIES:

1. Air conditioning, architecture and building, refrigeration, sewage and water.
2. Communications, power.
3. Agriculture, beverage, dairy, fermentation, food, sugar, starch.

4. Fuel, solids; fuel, gases; petroleum refining and production, rubber, atomic energy.
5. Ceramics, glass, pulp and paper, wood products.
6. Laundry soap and detergents, textile.
7. Graphic arts, instruments, jewelry, photography.

8. Chemical manufacturing, distilled liquor, electroplating, leather and tanning, metal fabrication and finishing, pharmaceuticals.
9. Aircraft, automotive, pipe line, railroad, shipping.
10. Explosives, metallurgy, mining ordnance and war materials, other.

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VOLUME 13

JANUARY THROUGH DECEMBER

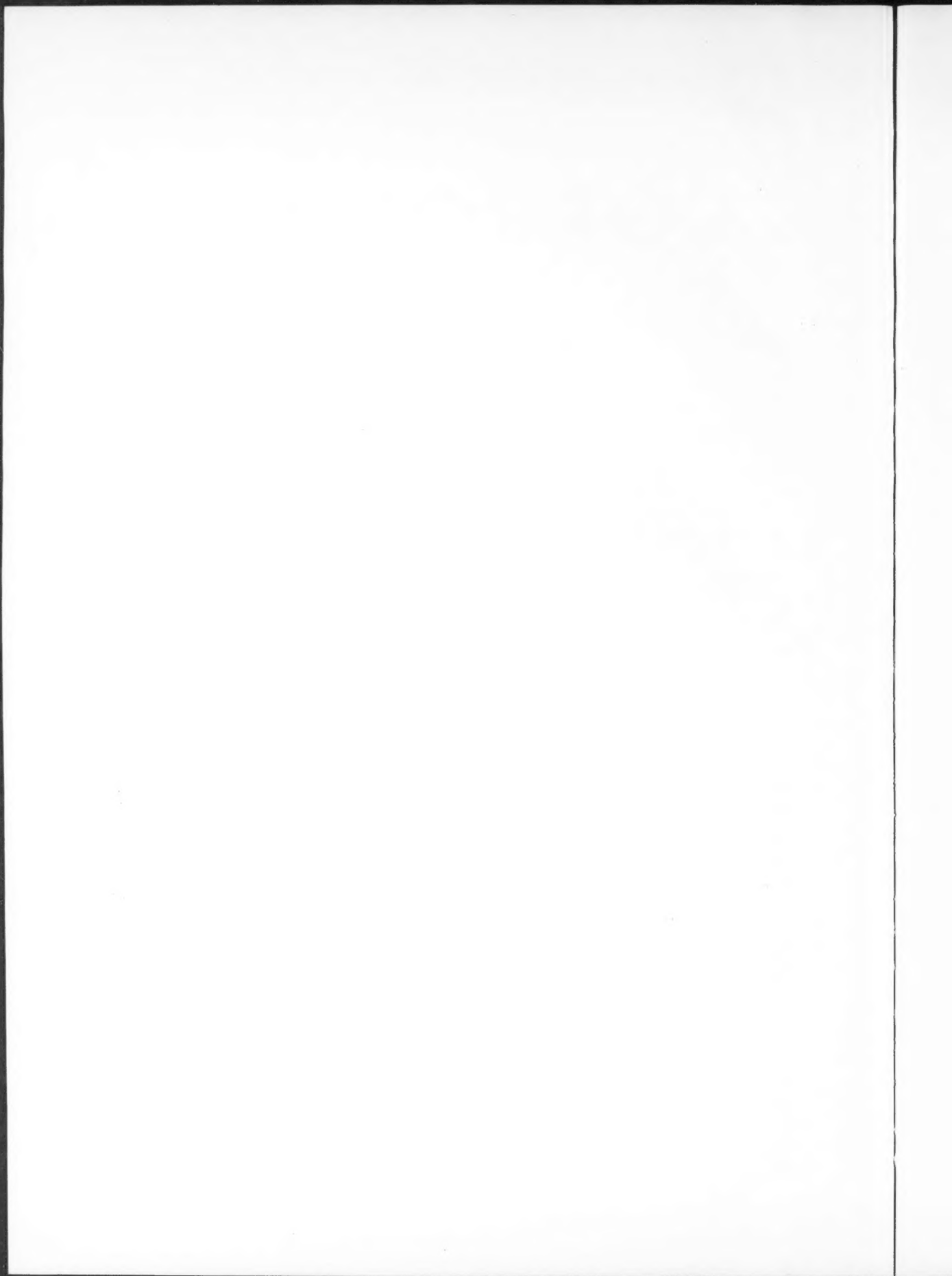
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ERRATA—CORROSION, Volumes 12 and 13

Calculation of the pH of Oil Well Waters by Walter F. Rogers. *Corrosion*, Vol. 12, No. 12, 595t-601t (1956) Dec.

Page 596t, Column 1, Equation (2) should read:

$$W_{\text{CO}_2} - W/L = m P_{\text{CO}_2} + b \quad (2)$$

Page 598t, Column 2, Equation (16) should read:

$$\text{pH} = 6.5 + \text{Log} (\text{HCO}_3^-) - \text{Log} (\text{H}_2\text{CO}_3) \quad (16)$$

Some Case Histories of Stress Corrosion Cracking of Austenitic Stainless Steels Associated with Chlorides by H. R. Copson and C. F. Cheng. *Corrosion*, Vol. 13, No 6, 397t-404t (1957) June.

On page 398t the caption for illustration identified as Figure 2 should read as follows:

Figure 7—Cross section through stainless clad steel of Case 7 showing cracks stopping at the steel. Nital etch, 25X.

On page 399t the captions for illustrations identified as Figures 3, 4, 5 and 6 should read respectively:

Figure 8—Section through expansion joint of Case 10 showing cracking at inside surface. Electrolytic oxalic acid etch, 250X.

Figure 9—One of the cracked disc specimens of Case 11.

Figure 4—Part of screw conveyor of Case 13 showing cracks. 1/2X.

Figure 10—Part of flash shield of Case 14 showing cracks. 1X.

On page 400t the captions for illustrations identified as Figures 7 and 8 should read respectively:

Figure 2—Cross section of flash shield of Case 14 showing cracks. Electrolytic oxalic acid etch, 100X.

Figure 5—One of the cracked disc specimens of Case 15. 1X.

On page 402t the captions for illustrations identified as Figures 9 and 10 should read respectively:

Figure 6—Cracking in bottom of kettle of Case 17. 1X.

Figure 3—Cross section of stainless steel of Case 21 showing cracking. Etched with glyceresia, 100X.

The Performance of Alcan 65S-T6 Aluminum Alloy Embedded in Certain Woods Under Marine Conditions by T. E. Wright, H. P. Godard and I. H. Jenks. *Corrosion*, Vol. 13, 481t-487t (1957) July.

Page 487t, Reference 1 should read:

I. P. M. Aziz. Application of the Statistical Theory of Extreme Values to the Analysis of Maximum Pit Depth Data For Aluminum. *Corrosion*, 12, 495t-506t (1956) Oct.

SECOND SECTION

COMICS

PHOTOGRAPHY

New York World-Telegram

The ~~World~~ Sun

NEW YORK, TUESDAY, DECEMBER 18, 1956

SECOND SECTION

EDITORIALS

SPORTS—FINANCE

Drive to Windy City on Turnpikes Now Is 13-Hour Breeze

Windy City is graphically shown above. Follow the dark line, from right to left, and you'll find the key mileage points, the times and the toll costs.

Ellenville Seeking Head for New Bank

Appeared in World-Telegram and Sun, ELLENVILLE, N. Y., Dec. 18. Five or six hundred dollars, which were over \$100,000, of the initial big in "Several of the initial big in "have taken" they will stock.

Brookville Police Official a Suicide

Special to World-Telegram and Sun, SEA CLIFF, L. I., Dec. 18.—Gordon Harvey, 42, police commissioner of one of the Brookville.

Highway Building Has Come of Age, Quick Trip Shows

By ARNOLD BENIN, Staff Writer.

The highway builders have caught up with the auto makers.

Proof? You can now drive from New York to Chicago without seeing a stop light and without crossing an intersection. You can make the run from city line to city line in 13 or 14 hours.

The trip really points up how much highway building has come of age. In pre-turnpike days it took the same time to drive to Pittsburgh—and that's only halfway to Chicago.

We know it can be done because we did it. This writer and photographer Ed Ford left New York at 3:20 a.m. (EST) and took the 13-hour drive to Pittsburgh. For the next part you traveled through the mountains, crossed the Chicago city line at 6:20 p.m. (EST), exactly 13 hours after leaving New York.

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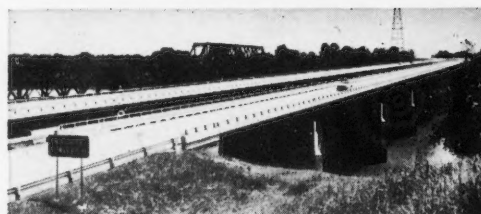
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